D.S. Hill

Pests of Crops in Warmer Climates and Their Control





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Preface

The original project was to produce a textbook for teaching agricultural entomology in the tropics (initially in Uganda) as at the time no suitable text was available. The accumulation of information for that compilation was generally regarded as successful; the first two editions published by C.U.P. are out of print and it was thought that a new version would be timely.

In the UK Europe and North America there are various textbooks available in English, but none gives an overall (international) view of the subject and none has quite the same approach as this, where large amounts of information have been incorporated into a summarized form for easy assimilation.

Initially only insect and mite pests were included, but it was felt useful to mention some of the other important pest animals.

The sources of information are many, and are listed in the bibliography; some are referred to in the text. In a number of cases the original publication was not seen; the information was taken from a review article or from an abstract.

Specimens for drawing were either personally collected or loaned from various institutions or collections, especially from the British Museum (Natural History) through the Keepers of Entomology (Dr P. Freeman, and Dr L. Mound), and the Trustees are thanked. Drawings were made by Hilary Broad, Karen Phillipps, and Alan Forster; a few were from other sources. Photographs were mostly taken by the author, but a few were from other sources and have appropriate acknowledgement under the plate.

Identifications of insect specimens were made by staff of the Commonwealth Institute of Entomology and the Department of Entomology, British Museum (Natural History), who were also sources of general information and advice.

Initial support for the project was made by the Rockefeller Foundation through a grant to the Faculty of Agriculture, Makerere University, Uganda.

General facilities were made available by the Department of Zoology, University of Hong Kong, Alemaya University of Agriculture, Ethiopia, and University of Malaysia Sarawak.

The successful completion of this project would not have been possible without the help of many colleagues, especially those from ADAS, and the Harpenden Laboratory of MAFF; also from Rothamsted Experimental Station, from FAO (Rome) and from many chemical companies.

I would like to take this opportunity to thank specifically the following for their help in many different ways: Dr D.V. Alford, Mr R. Bardner, Dr V.F. Eastop, Susan D. Hainsworth, Mr C. Furk, Mr T.J. Crowe, Dr D.J. Greathead, Mr A. Lane, Dr Lee, Hay Yue, Mr R.J.A.W. Lever, Dr Li, Li-ying, Dr W. Linke, Professor B. Lofts, Professor J.L. Nickel, Professor J.G. Phillips, Mr G. Rose, Dr K.A. Spencer, Dr D.L. Struble, Dr J.D. Sudd and Mr R. Wong.

Dennis S. Hill
April, 2007



This book is dedicated to Dr John L. Nickel and Terry Crowe without whose support the original project could never have started.

Contents

1 *Introduction*

This book is intended for use as a student text for courses in 'Applied entomology', 'Crop pests' and 'Crop protection'. at both undergraduate and post-graduate level. It presupposes a basic knowledge of entomology to the level of that in Imms, A.D. (1960) *A general textbook of entomology*, or alternatively Borror, D.J. & D.M. Delong (1971) *An introduction to the study of insects*. In other words, the reader should be acquainted with the major groups of insects and their characteristics, which may mean order, suborder or superfamily in some cases, but in the more economically important orders this would mean familiarity with superfamilies or families, for example in the Hemiptera, Lepidoptera, Coleoptera, and Diptera.

There is more information in the 10th Edition of 'Imms' (Richards & Davies, 1977), but this is now so expensive that most students are probably still using the previous edition.

It is hoped that some sections of the book will also serve for reference purposes, as these sections represent the distillation of much information acquired by extensive experience and detailed literature searching.

Certain tropical crops, such as rice and citrus fruit, can be cultivated in countries outside the tropics. A recent trend in many countries is to make the effort to diversify local agricultural crops: in the tropics many temperate crops are now being grown in cooler locations, and in temperate countries some tropical crops are being successfully grown both in greenhouses and in the open. The breeding of new varieties of crops has made the more widespread cultivation more feasible.

Because of the escalating costs of publication the overall size of the book is limited and so the number of pests and crops studied in detail is less than desired. In an attempt to compensate for this the pest section is aimed at generic level rather than individual species, where possible; some pests are pantropical at the genus level, occurring as several distinct allopatric species. Where an important group of pests is only sparsely represented then a brief review of the group is presented in a couple of pages of text.

To make it as clear as possible which insect species are being referred to in the text both the scientific name (genus and species) and a suitable common name are used in conjunction. Unfortunately there is a lack of international agreement over the use of names, despite the efforts of the *International Code of Zoological Nomenclature*. Similarly with the different taxa used: what is often regarded as a distinct family in one country may be relegated to subfamily status in another. In this respect the present text shows a bias towards the classification used in the UK, and particularly that employed in 'Imms' *General textbook of entomology*, 10th edition, by Richards & Davies (1977).

In a text such as this, where the aim is an international coverage, inevitably some names given here will differ from those used in other parts of the world, but hopefully the identity of the pest will not be in doubt. The scientific names given in the book are those used by the Commonwealth Institute of Entomology (CIE) on their distribution maps, and those listed in Seymour (1979) and Kloet & Hincks (2nd edition – revised, 1964–78) for the UK, Werner (1982) for the USA, and the checklists for China, Japan, Australia, etc., listed in the bibliography. Clearly, some of these major publications are already out of date, and some major name changes have taken place very recently, within the last year or two.

The question as to whether very recent name changes for insect pests should be followed in a student text is very vexing. The taxonomic purists will, of course, insist that all name changes be strictly adhered to. But in many parts of the world the news of such name changes is slow to arrive, and so far as students are concerned the great majority of their reference sources, if not all, will be using the previous name for the pest, if not even earlier ones. As a practical entomologist I am loathe to see well established names being changed, unless really necessary, because of the confusion that will ensue. But of course, if there is good reason for the name change then it must be accepted. In chapter 9, where individual pest species are described, if there has been a recent name change the former name is included in parentheses as a synonym, or whatever. Older previous names are not included, for many of the widespread crop pests have lists of synonyms and misidentifications of interminable length.

The common names used are from the same sources generally as the scientific names. There are considerable divergences in usage of common names; for example in Europe it is traditional to refer to the adult insect (such as Onion Fly) whereas in the New World the damaging stage is referred to (that is Onion Maggot); but in these cases the identity is fairly obvious. In some cases though, for the purpose of this text, an arbitrary choice of common names has had to be made as to the more appropriate when used internationally.

It should be stressed that some records are taken from local or regional publications, and sometimes there are complications in that a particular pest may either have been misidentified or else have been identified correctly but referred to by an invalid name. Sometimes the use of an invalid scientific name is obvious and the record can be rectified, but with some less well-known species it may not be evident, and so some incorrect names will inevitably be included.

Finally it should be remembered that the writing of many book manuscripts takes several years, and then actual publication generally takes 1–2 years to complete, so it is inevitable that the published book will be out of

date scientifically, both with regard to names used and also pesticides and their recommendations, even on the day of release. But hopefully by the combined use of scientific and common names for each pest it will be clear as to the identity of the organism concerned.

The distributions given are summarized from the maps produced by the CIE, and in the cases where a map has not been produced for a particular species the appropriate distribution data have been made available from the CIE card index system (now computerized). Reference to the CIE map, where one is available, is made at the end of each summary of distribution.

In the section on control, emphasis has been placed on methods of cultural control whenever these are available, and so far as pesticides are concerned no details as to rates, etc., are included. Pesticide recommendations vary extensively from country to country, and also from season to season, so only the barest details of pesticide recommendations are included. For full details of these for local crops in each country, the appropriate Ministry or Department of Agriculture or Regional Entomologist should be consulted. It would be quite impossible to provide adequate pesticide detail suitable for practical use in all the different parts of the tropical world.

When considering some aspects of the basic principles underlying the study of crop pests and their control, some of the examples given are from non-tropical situations. They are used because they are particularly suitable as examples, and are usually very well-known pests.

The section on pesticides was compiled from data published in *The Pesticide Manual* (A World Compendium) (10th Edn) (Tomlin, 1994), and from various original data sheets provided by the firms concerned, and that part dealing with application equipment largely from Matthews (1979). It is not feasible to generalize extensively about persistence, efficiency, pre-harvest intervals, toxicity, and tolerance levels, for not only do these characteristics vary considerably according to local climatic conditions, but each country has its own requirements with regard to residues and toxicity. Some countries are more concerned with operator safety, whereas others regard consumer hazards the more important. Thus the same chemical may have a pre-harvest interval of seven days in one country and as many as 28 in another: or alternatively an approved pesticide in one country may be banned in another.

In chapter 9 on pest descriptions, biology and control measures, the original scheme was to illustrate all the important stages of the major insect pests and to show the damage done to the host. But it was not possible to provide all stages and damage for more than 300 major pests, and so in some cases only the adult insect is drawn. Unfortunately, some of the earlier drawings were designed more to give an impression of the pest and the crop plant rather than accurate detail of the insect. In the more recent drawings by Hilary Broad Alan Forster, and Karen Phillipps we have endeavoured to reproduce morphological details which are taxonomically specific.

The species here designated as major pests have, in a few instances, been chosen for academic reasons or to demonstrate a point of particular biological interest rather than always being primarily economic pests. I have attempted to include a well-balanced range of pests, most of which are important on major crops, and widely distributed throughout the warmer parts of the world. The denotation of the term 'major pest' to a species is necessarily somewhat arbitrary when dealing with 100 crops grown throughout the warmer parts of the world. However, this term has usually only been applied to species which are economically important over a wide part of the range in which the crop is cultivated.

According to figures provided by Dr R.G. Fennah for Wilson (1971) it can be said that there are some 30 000 insect pest species, but Fletcher (1974) referred to there being only about 1000. Later in the book he mentioned that the total number of insect and mite pests species recorded from several major crops ranges from 1400 on cocoa and cotton to 838 on coffee. It seems reasonable to assume that on a worldwide basis there is something in the region of 1000 species of 'serious' crop pest species, including pests of forests and ornamentals, and may be up to 30 000 minor pest species. In chapter 10, under the headings of the 100 crops considered, are listed the more important major pests, many of which were included in chapter 9, and in addition a selection of the minor pests recorded from each crop. In some of the more restricted crops the number of recorded pest species is very small, whereas the widespread crops may have more than 1000 recorded minor pests. In these cases the list of minor pests has been restricted to the more important, more interesting, or more widespread of the minor pest species.

2 *Pest ecology*

The information provided in this chapter has been separated off in an attempt to emphasize the need for a greater understanding of the complex ecological relationships between the insects and plants in the agricultural context. Here are also included various aspects of basic biology that have broad ecological relevance. There is clearly overlap between this and the next chapter, as various factors in the consideration of basic principles relating to pest control are aspects of the pest/crop ecology.

Ecology and pest control

The earliest recorded attempts at pest control were often basically concerned with the biology of the pests and their ecology, and attempts were made to make the environment less favourable for the pests by various physical and cultural means. With the recent disillusionment with pesticides and with the increased awareness of the importance of ecological aspects of the pest/crop situation, as now defined by most integrated pest management (IPM) programmes, there has been a reversal of approach to basic ecological aspects.

Ecology

The complex and interacting system comprising all the living organisms of an area, and their physical environment (soil, water, climate, shelter etc.) is termed the *ecosystem*, and the study of ecosystems is called *ecology*. Definitions of ecology vary according to the speciality of the definer: botanists often have a different viewpoint from zoologists, and agriculturalists may have a third view. In its simplest form ecology can be defined as 'the total relationships of the plants and animals of an area (habitat) to each other, and to their environment'.

Environment has been defined by Andrewartha & Birch (1961) as being composed of four main factors: weather, food, other animals and plants, and shelter (a place in which to live).

For convenience it is customary to lump together environmental factors into two broad categories, biotic (i.e. organic) and physical (i.e. abiotic or inorganic). Weather and shelter (usually) are clearly physical factors, although shelter for a parasite could be regarded as biotic. Other animals and plants clearly constitute a biotic factor. Food is a biotic factor for animals which are holozoic (heterotrophic) in their feeding habits, but could possibly be more suitably described as physical for plants, which are holophytic (autotrophic) in their nutrition.

The *environmental factors* can be further defined as follows.

Weather

(a) Temperature – ranges defined as tropical, temperate, arctic or boreal
(b) Humidity – ranges from moist, moderate, to dry conditions
(c) Water – includes groundwater, rainfall, etc.
(d) Light – intensity important for many organisms
(e) Wind – important for dispersal, and drying effects

Food

(a) For animals
    (i) Organic remains – detritivores
    (ii) Plant material – herbivores (phytophagous)
    (iii) Other animals – carnivores and parasites
(b) For plants
    (i) Organic remains – saprophytes (mostly fungi and bacteria)
    (ii) Other plants – parasites and pathogens
    (iii) Animals – insectivores (carnivores)
    (iv) Sunlight, water, carbon dioxide, minerals, chlorophyll (autotrophs)

Other animals and plants (i.e. the community)

(a) Competition – intraspecific (within the species)
– interspecific (between different species)
(b) Predation
(c) Parasitism
(d) Pathogens causing diseases

Shelter (a place in which to live; habitat)

(a) For animals (insects) and pathogens – frequently a plant, and often a specific location on the plant, e.g. in the cases of a leaf-miner, stem borer, bollworm and leaf-roller. Some insects are soil-dwellers (e.g. termites, crickets, beetle larvae), and adult, winged insects may not be very habitat-specific (i.e. eurytopic).
(b) For plants – usually a physical location (habitat), including the soil (e.g. hilltop, valley, field) together with the other plants that constitute the community.

Two basic ecological terms should perhaps be included here for reference.

Habitat. The place where the plants and animals live; usually with a distinctive boundary, e.g. a field, pond, stream, sand-dune or rocky crevice. Often initially broadly subdivided into terrestrial, marine, and freshwater habitats

Community. The collection of different species and types of plants and animals, in their respective niches, within the common habitat, e.g. lake community, mangrove community

or ravine community. The basic plan for all communities is the same, i.e. they are composed of saprophytes, autotrophic plants, detritivores, herbivores, carnivores, parasites, etc.

With the general disillusionment that followed the widespread continual use of synthetic chemical pesticides, especially the early organochlorine compounds, the situation has changed so that now attention is focussed on biological and ecological understanding, linked with careful application of selected pesticides. This approach was initially called *integrated control* but was more recently redefined as *pest management* (PM), and is now finally referred to as *integrated pest management* (IPM).

As indicated above, the number of different factors operating in an insect pest host plant relationship is large and hence the different possibilities available for ecological manipulation are considerable. But, of course, a vital prerequisite is a detailed knowledge of the insect's life-history and biology, and especially its relationship with the host plant.

As mentioned later (p.5), an insect species is only a pest (that is an economic pest) at or above a certain population density, and in any pest ecosystem any one (or more) aspect of the environment may be of over-riding importance. In the study of pest populations the key to control will inevitably lie in the understanding of the complex of environmental factors and their relative importance. However, our knowledge at present of most pest situations falls short of this ideal, and much basic ecological study is still required. Too frequently pest control still consists of hastily and ill-considered applications of chemical pesticides, which sometimes wreak ecological havoc, especially in the tropics, often without controlling the pest at which they were aimed. Progress is gradually being made though, as evidenced by the ever-growing number of IPM programmes for different crops in different parts of the world.

Agroecosystems

An agroecosystem is basically the ecosystem of an area as modified by the practice of agriculture, horticulture or animal rearing. Agriculture consists of methods of soil management and plant cultivation so as to maintain a continuous maximum yield of crop produce, in the shortest time possible. This is achieved by manipulation of the environment so as to make growing conditions for the crop plants as near ideal as possible, and also to minimize damage to the crop by pest and disease attacks. Obvious manipulations are listed below, under the appropriate environmental headings.

Weather

(a) Temperature control by shading (lowering) or use of greenhouse (raising)
(b) Humidity control by spraying or altering plant density
(c) Irrigation (below or above-ground) and drainage
(d) Light increased by use of ultra-violet lamps, or reduced by shade trees, shelter, etc.
(e) Wind protection by growing shelter-belts, windbreaks, tall trees and hedgerows

Food

(a) Animal feedstuff, grazing leys, dietary supplements
(b) Plants are 'fed' by addition of fertilizers, minerals, and trace elements; sometimes increased radiation by use of extra illumination

Competition – intraspecific, reduced by careful crop spacing
– interspecific, reduced by weeding and use of herbicides

Predation, parasitism and disease reduced by crop protection procedures

Shelter

(a) Animal houses
(b) Windbreaks, shelter-belts, greenhouses, polythene shelters, protected seedbeds, etc. Also soil improvement by drainage, irrigation, liming, fertilizers, deep ploughing, hardpan breaking, manuring etc.

Thus it is clear that every aspect of the environment can be (and usually is) manipulated in the course of modern sophisticated agriculture. Generally though, only practices that show a definite economic profit are indulged.

The major ecological modifications that are made during the process of agriculture (*sensu lato*) that affect pest populations are as follows.

Monoculture – the extensive growth of a single plant species, with a simplification of the flora, partly by weed destruction.

Increased edibility of crop plants – the crop plants are more succulent, larger and generally more attractive to pests than the wild progenitors.

Multiplication of suitable habitats – the habitat and the microclimate becomes uniform over a large area.

Loss of competing species – may lead to the formation of new pests.

Change of host/parasite relationships – will lead to the development of secondary pests.

Spread of pests by man – as crops are grown in more parts of the world, the pests are also eventually spread around by accident.

These and other topics will be looked at in more detail in later sections of this chapter.

It should be stressed at this point that the vast majority of crop pests are in fact human-created through the ancient practice of agriculture. Completely 'natural' serious crop pests are very few and are limited to locusts, possibly a few tropical armyworms, and some defoliating caterpillars and sawfly larvae that occur in the extensive natural semi-monocultures of the northern taiga in N. Europe, N. Asia, and N. America and the northern deciduous forests.

Pest populations

The important point to remember about any pest is that it is only an economic pest at or above a certain population density, and that usually the control measures employed against it are designed only to lower the population below the density at which the insect is considered to be an economic pest; only very rarely is complete eradication of the pest aimed at. The schematic representation of the growth of a population in fig. 1 (adapted from Allee *et al*, 1955) has had four separate population levels indicated; these are represented by the numbers 1 to 4. These population levels indicate purely hypothetical densities at which any particular insect species may be designated an, economic pest. Population level 1 might well represent an economic pest level for such an insect as Rosy Apple Aphid (*Dysaphis plantaginea*), for in this case control measures are recommended when the population density reaches one aphid per tree (at bud-burst), and similarly for a pest such as Colorado Beetle.

At the other extreme population level 4 could well apply to insects such as various cutworms which are only economic pests in Europe at irregular intervals at times of population irruption. Most of the more common pests would come into the categories which reach pest density at population levels 2 and 3. The growth of a population can be expressed very simply in the equation:

$$P_2 \leftrightharpoons P_1 + N - M \pm D,$$

Where P_2 = final population, P_1 = initial population, N = natality, M = mortality, D = dispersal.

To simplify this equation, natality can be regarded as synonymous with birthrate, mortality with deathrate, and dispersal is either regarded as movement out of the population (emigration), or movement into the population from outside (immigration). The object of pest control is to lower P_2, which quite clearly can be done by either lowering the birthrate of the pest, increasing the deathrate, or inducing the pest to emigrate away from the area concerned.

Four hypothetical pest populations are illustrated graphically in Stern, Smith, van den Bosch & Hagen, (1959), in relation to their equilibrium position, economic threshold, and economic injury levels; these graphs are illustrated in fig. 2.

Life-table

The examination of a pest population and its separation into the different age-group components, i.e. eggs, larvae, pupae and adults, enables a life-table for that pest population to be compiled. The construction of a life-table for a pest species is an important component in the understanding of its popu-

Fig. 1. The growth of populations (after Allee *et al*., 1955).
Stage I Period of positive, sigmoid growth; population increasing
A Establishment of population
B Period of rapid growth (exponential growth)
C Population levelling off
II Equilibrium position (asymptote); numerical stability
III Oscillations and fluctuations
A Oscillations – symmetrical departures from equilibrium
B Fluctuations – asymmetrical departures
IV Period of population decline (negative growth)
V Extinction

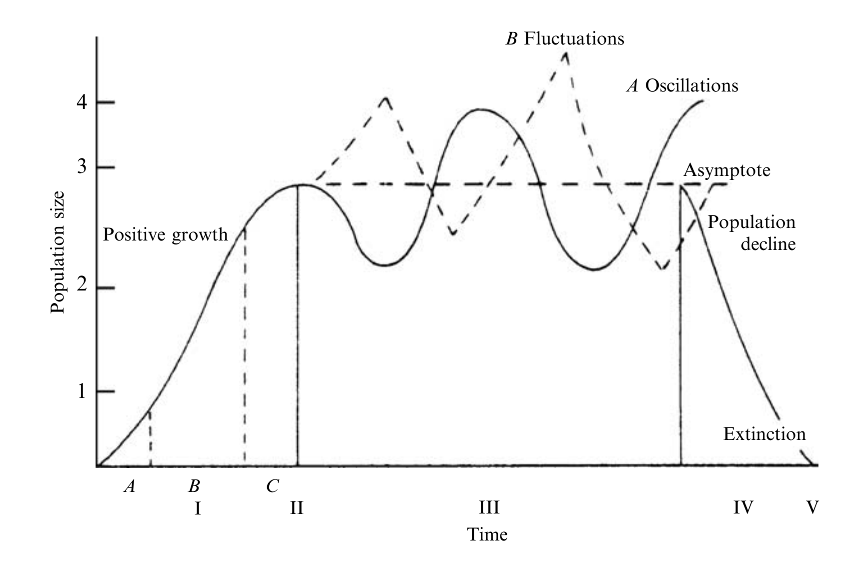
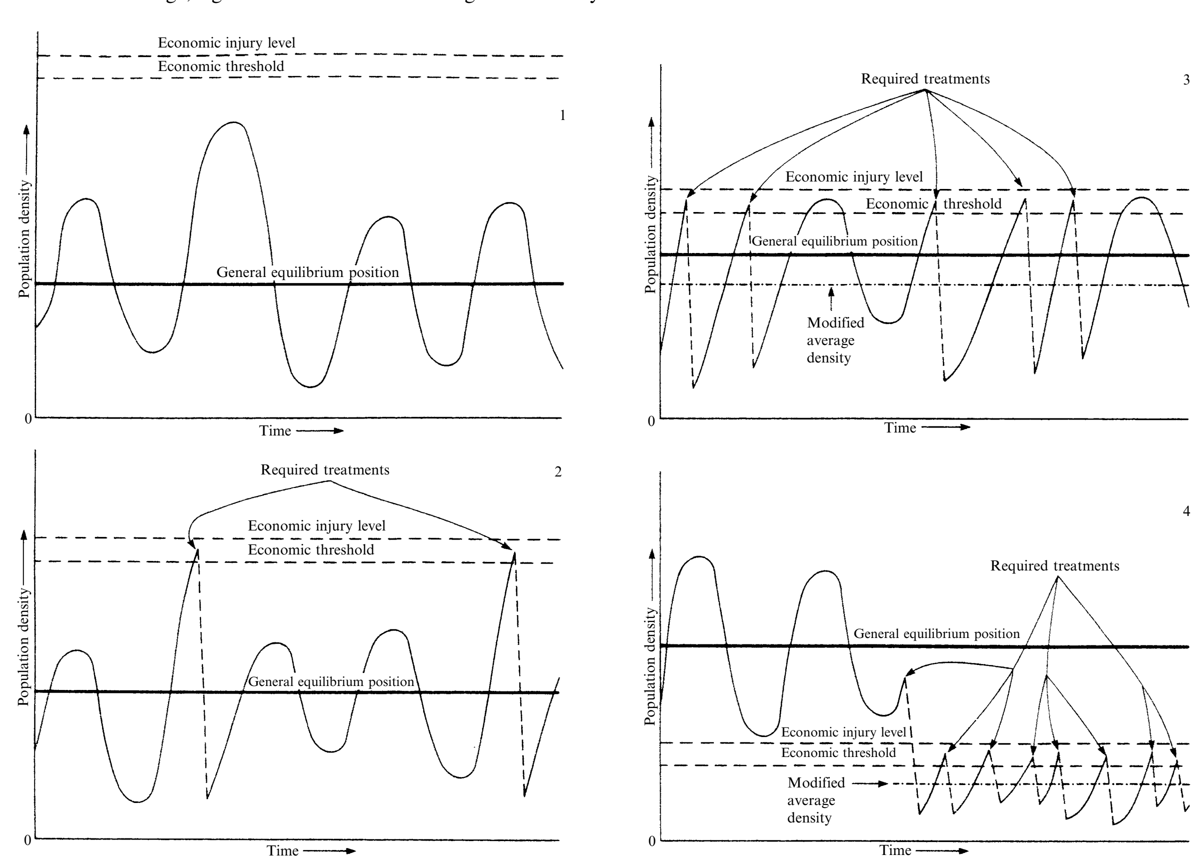


Fig. 2. Schematic graphs of the fluctuations of four theoretical arthropod populations in relation to their general equilibrium position, economic threshold and economic injury levels (from Stern *et al.*, 1959).
1. Non-economic species whose general equilibrium position and highest populations are below the economic threshold, e.g. *Aphis medicaginis* on alfalfa in California, USA.
2. Occasional pest whose general equilibrium position is below the economic threshold, but whose highest population fluctuations exceed the economic threshold, e.g. *Cydia molesta* on peaches in California, USA.
3. Perennial pest whose general equilibrium position is below the economic threshold, but whose population fluctuations frequently exceed the economic threshold, e.g. *Lygus* spp. on seed alfalfa in western USA.
4. Serious pest whose general equilibrium position is above the economic threshold, usually requiring insecticide application to prevent economic damage, e.g. *Musca domestica* in milking sheds of dairy farms.



lation dynamics, particularly in relation to natural predation and mortality, and is, in point of fact, a vital part of any IPM programme. The growth of an insect population, especially the recruitment and the survival of the different stages, varies considerably according to the type of insect concerned. One result of this variation is that there are half-a-dozen different methods for the construction of a *budget* (for further details see chapters 10 and 11 in Southwood (1978)). As pointed out by Harcourt (1969), it is necessary to be careful in the choice of the appropriate method for compiling a life-table budget when planning the sampling methods to be used.

Resurgence

The term resurgence is used to express a sudden increase in population numbers. One type occurs when the target species, which was initially suppressed by the insecticidal treatment, undergoes rapid recovery after the decline of the treatment effect.

It may also occur as a result of the development of a new biotype of the pest, or if the insecticide treatment kills a disproportionate number of the natural enemies of the pest species.

Population fluctuations

Insect populations are frequently subjected to dramatic fluctuations and this is especially true for pest species that have an unlimited food supply. Often the cause lies with the natural parasites and predators, such as with some pests of cocoa and oil palm in S.E. Asia, but sometimes it is inexplicable. In Sarawak in 2002 a croton bush was heavily infested with mealybugs (Fig. 3.1) – it had been like this for eight months, and then suddenly within a period of 14 days the infestation completely disappeared (Fig. 3.2).

Population dynamics theory

(After Southwood, 1977.) Applied biologists have for a long time been concerned with two basic aspects of

Fig. 3.1. Mealybug infestation of Croton foliage, BDC estate. September, 2002. All stems were heavily infested.



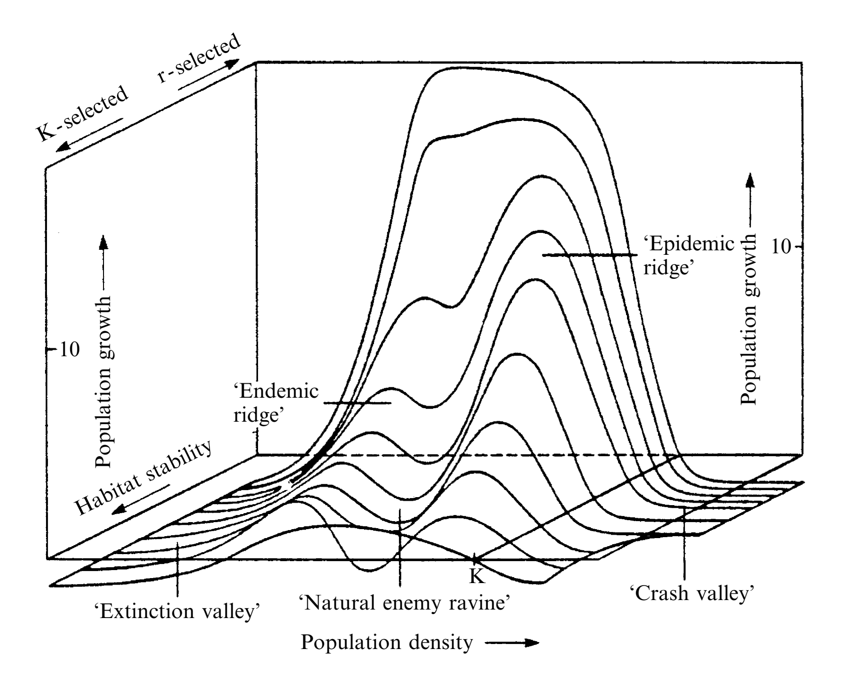
Fig. 3.2. Mealybug infestation completely disappeared after 10 days. October, 2002. B.D.C.



animal numbers: firstly that population numbers may change greatly, as pointed out by Andrewartha & Birch (1954), and secondly that most animal populations are relatively stable in comparison with their prodigious powers of increase. It now seems that certain species of animals belong to the one category and others to the second. Southwood pointed out that the change of the population fluctuation to a state of stability is associated with an increasing duration of stability in the habitat, and may be conveniently equated with the *r–K continuum. r-strategists* are opportunists, living in temporary (ephemeral) habitats and adapted to obtain maximum food intake in a short time; they are generally small, mobile and migratory, and have a short generation time. *K-strategists* live in stable habitats, often in crowded conditions, with their population size near the carrying capacity of their habitat; they are usually larger in size, less migratory and have a long generation time.

Fig. 3 is a synoptic population model. Three regions can be recognized. First the r-strategists, whose habitats are ephemeral and whose numbers are characteristically 'boom and bust': this strategy is dominated by large-scale migration, massive population losses, and new populations continually developing from a handful of colonizers. Secondly, the K-strategists represent the other extreme, maintaining a steady population at or near the carrying capacity of the habitat, basically in equilibrium with their resources; recruitment, mortality, and migration are low, so there is less opportunity to adapt to changed environments. These animals are specialized to their particular environment, and if their numbers are reduced to a low level they are liable to become extinct.

Fig. 3. The synoptic population model (after Southwood & Comins, 1976). K = carrying capacity (as in K-selected)
Note: equilibrium points only occur where an 'east-facing slope' cuts a zero population growth contour, as only here does negative feedback occur.



Finally, the middle region recognized is the 'natural enemy ravine'. Both kinds of strategists have a stable equilibrium point, the upper one at the population density of the carrying capacity of the habitat. Where the 'natural enemy ravine' dips below the zero population growth contour there is a second equilibrium point, and where it rises through the contour on the other side of the ravine is the release, or escape, point from natural enemies. Above this point, in the absence of density-independent catastrophes, the population rises to the upper equilibrium point where intraspecific competition mechanisms (disease, etc.) operate. These two levels have been referred to as the endemic (lower) level and the epidemic (upper) level.

r-pests include species such as locusts, armyworms, leafhoppers, aphids, planthoppers, many flies, and, in plants, the ruderals (weeds) belong to this category. *K-pests* include elephants in Africa, tapeworms, Codling Moth, ants, tsetse flies, and many beetles. Obviously the r- and K-pests represent the extremes of a continuum, and there is correspondingly a large group of *intermediate pests*. It is with this large group that natural enemies have most population impact.

Applied biologists generally appreciate that habitat characters are important indicators for IPM strategies, and Conway (in May, 1976) has shown that as the r–K continuum is related to habitat characteristics it is relevant to decisions on the choice of a particular control strategy.

Insect pest diversity (competitive exclusion)

Many zoology students have been taught the idea that no two animal species can occupy the same ecological niche without one species (the 'stronger') replacing the other (the 'weaker') over a period of time. Supporting evidence was usually an experiment carried out by Gause in 1934: he kept *Paramecium aurelia* and *P. caudatum* together in nutritive fluid in a small container; after about three weeks the latter species was exterminated. This idea is generally referred to as 'Gause's hypothesis', or 'the principle of competitive exclusion'. By definition this refers to the exclusion of one species by another when they compete for a common resource (often food) that is in limited supply; the principle being that two species with identical ecological requirements cannot coexist indefinitely.

It would seem that the basic principle of competitive exclusion is clearly valid, and it may be a factor of importance in evolution. But the *Paramecium* experiment was clearly a very simple case where both species ate the same simple food within an enclosed habitat, and as such represented a very artificial situation. For most phytophagous insects either the food sources are not limited, or else the ecological requirements of the different insect species are not identical, even though they may be quite similar.

When a student finds a particular crop pest species *in situ* on a host plant, frequently the assumption is made that 'that niche is clearly occupied so there will not be another species in that microhabitat'! In practice the converse situation prevails, as is generally recognized by most experienced field biologists: if one particular insect species is found on a plant at a particular location on the plant body, then the student should expect to find other species at the same location. It should never be assumed that an infestation

is a single-species population; it is actually preferable to assume that each infestation may be a mixed population of several closely related (or otherwise) species, until proven otherwise. Many ecological studies have failed because of the inability of the observer/recorder to recognize a mixed-species population.

Thus it should be expected that many natural animal populations are likely to be composed of several (often closely-related) species, sometimes very similar in appearance and occasionally indistinguishable morphologically. Common examples in agricultural entomology include the following: the stalkborer complex on maize, rice, sorghum and sugarcane (Lep., Pyralidae, Noctuidae); scale insects on *Citrus*; mealybugs on sugarcane; aphids on lettuce; aphids on potato; leafminers on apple; chafer grubs eating the roots of sugarcane; weevil larvae eating roots of strawberry.

On many agricultural crops, food for an insect pest can be regarded as virtually unlimited; also most closely related insects have slight differences in their basic ecology or diet, so in most insect/crop plant situations the concept of competitive exclusion does not apply.

Insect pheromones in relation to pest control

Pheromones, originally referred to as ectohormones, are complex chemical compounds, basically long-chain hydrocarbons such as alcohols, esters, ketones, aldehydes and sometimes ethers. Many have now been successfully identified, and some synthesized; a number are now available commercially from some chemical companies, for pest monitoring or control purposes.

They are secretions from several different types of glands, on different parts of the insect body, which open directly to the exterior, the secretory product is usually airborne for its distribution. Their basic function is for communication of a specific type between individuals of the same species, and the chemical elicits a specific reaction in the receiving individual. Within the large, complex, social colonies of ants, bees, wasps and termites, apparently quite sophisticated systems of communication have evolved, mostly based upon the use of pheromones.

The term 'pheromone' is usually regarded in a behavioural context in that it is a chemical or chemical complex that elicits a specific behavioural response in the receiving insect. Apparently some glands secrete a single chemical, whereas others secrete several which appear to act in concert. Generally there has been no overall agreement for a scheme of classification, but most workers favour the basis to be the type of behaviour released in the receiving insect. One approach is to consider them to be of two basic types, those which give a releaser effect (this entailing a more or less immediate and reversible effect on the behaviour of the recipient), the others having a primer effect (this starting a chain of physiological events in the receiving insect). The latter group are usually gustatory in operation and typically control the social behaviour in Hymenoptera and Isoptera. Behaviour-releasing pheromones are typically odorous and their action is direct upon the central nervous system of the recipient, usually through the chemoreceptors in the antennae.

Recent work has demonstrated that most insect pheromones are in fact a complex of chemicals, and the individual chemicals are referred to as *components*. For example, the Smaller Tea Tortrix Moth sex pheromone has four components, two are major components and two are minor. Current opinion is that further research will reveal that almost all pheromones are actually chemical complexes of several compounds, and that the original idea of there being only one chemical present is completely incorrect, and originated because at the time the methods of chemical analysis were insufficiently sensitive to detect the minor components.

It is now apparent that much of the early work on insect pheromones is largely worthless (or, at best, of limited value) in that the researchers did not appreciate that almost invariably each pheromone was in fact a complex of major and minor components acting in concert on the receiving insect. Experimentation using only some of the chemical components of a particular pheromone inevitably led to anomalous results.

The types of behaviour (pheromones) used by Shorey (1976) were aggregation (including aerial and ground trail-following), dispersion, sexual, oviposition, alarm and specialized colonial behaviour. Some pheromones appear to have more than one function so these categories are of somewhat limited application.

Aggregation

The reasons for aggregation are numerous and varied, and include collection around or to a food source, a shelter site, a site for oviposition or colonization, recruitment of a sexual partner, and aggregation for swarming or dispersal purposes.

One of the most obvious cases can be seen by watching ants on their foraging trails, where the scouts are clearly laying scent trails. Trail-following by ants has been well studied. The scouts, after having located a food source, deposit droplets of pheromone on the ground and this stimulates trail-following behaviour amongst other workers. While the food source persists the ant workers continually reinforce the scent trail, but after depletion trail reinforcement ceases and the trail eventually disappears. Some trails are ephemeral but others persist for weeks or months. The Imported Fire Ant (*Solenopsis saevissima*) in the USA uses short-lived trails near the nest, but some species of Leaf-cutting Ant (*Atta* spp.) lay persistent trails to leaf sources up to 100 m distant which may last for months. Similar trails are laid by termites when foraging.

Bees and wasps (*Vespa vulgaris*) leave a scent trail from their feet which is important in delimiting the entrance to their nests.

Bark beetles (Scolytidae) use aggregation pheromones to designate host trees suitable for colonization, as these beetles only flourish when present in quite dense

populations. The pheromones are released from the hindgut of the beetle mixed with the various terpenoid compounds of the host tree which initially attracted the first invaders to the tree. These aggregation pheromones can be released by either sex and serve to attract individuals of both sexes. Colonization is usually succeeded by mating which involves the use of sexual pheromones. This type of aggregation can also be seen in the Japanese Beetle (*Popillia japonica*) and the Cotton Boll Weevil (*Anthonomus grandis*).

Certain mosquitoes release pheromones into the water at oviposition which attract other females. Sheep Blowfly (*Lucilia cuprina*) females apparently use an aggregation pheromone to form dense populations at sheep carcases for oviposition.

Aggregation at a suitable resting site has been demonstrated for the Bed Bug (*Cimex lectularis*) and some other cryptozoic species.

The mechanism for aggregation at a chemical source is usually chemotaxis where the insect can detect the gradient of odour molecules, and it often involves orientation by anemotaxis, that is positive orientation to air currents, particularly in the case of flying insects.

Dispersal

Dispersal is clearly the opposite of aggregation, but it is not encountered very often. However, some bark beetle males produce pheromones after mating which repel other males, and some female beetles release a repelling pheromone when they are unwilling to mate. *Tribolium confusum* females release a pheromone in the foodstuff they infest which repels other females and ensures a uniform population distribution throughout the available space. It is thought that the female Apple Fruit Fly leaves a pheromone trace on the apple surface after oviposition, for she can be seen to drag her ovipositor over the surface and generally other females do not lay their eggs in the same fruit.

It seems that some dispersal secretions are the same as the defence secretions; for instance, nymphs of *Dysdercus* produce stinking coxal gland secretions when disturbed (thought to be a defence against predators) which causes the gregarious bug nymphs to scatter. Certain species of ants have alarm pheromones which in some circumstances (in the nest) induce aggregation but under other conditions (away from the nest) result in dispersal.

Sexual behaviour

Sex pheromones may be produced in either sex and stimulate a series of behavioural sequences that usually results in mating. Typically, there appears to be a hierarchy of behavioural responses with increasing stimulation by sex pheromones. Once the two sexes are in proximity there is usually a close-range series of behavioural reactions, referred to as courtship behaviour.

The most usual situation is that a receptive virgin female insect will announce her availability through release of aerial sex pheromones, known as 'calling', and these cause a flight response and approach by receiving males. The night-flying moths (especially Saturniidae, Geometridae, and Noctuidae) are best known for their nocturnal emission of sex pheromones, which reputedly can attract males from as far as 5 km downwind. Males may produce a pheromone (sometimes called an 'aphrodisiac') when in the immediate vicinity of the female, which operates by inhibiting the female's tendency to fly away.

Sex pheromones are commonly referred to as 'sex attractants' or 'sex lures', which is misleading in that it implies that the odorous chemicals simply cause attraction, which is a great oversimplification. As will be discussed later, the male response to a female pheromone is complicated and sequential, involving half-a-dozen or more separate stages.

Most of the sex pheromones that have been isolated, identified and synthesized are from the Lepidoptera, and include Red Bollworm, Spiny Bollworm, Pink Bollworm, *Heliothis* spp., *Spodoptera littoralis*, *Chilo* spp., *Prays citri*, *Prays oleae*, Gypsy Moth, *Bombyx mori*, Cabbage Looper, Codling Moth, and Honey Bee queen. Pheromones of some of the most important fruit flies (Tephritidae) such as *Dacus* and *Ceratitis* spp. have also been synthesized, as have some for Scarab Beetles and Scolytidae. Many of the sex pheromones are either difficult to synthesize or else expensive to produce, and this has led to the development of chemical pheromone mimics for large-scale management programmes. These chemicals are discussed in the section on 'attractants' which follows later.

Oviposition

As already mentioned, Sheep Blowfly females release an aggregation pheromone when they oviposit on a suitable sheep carcase in Australia, and the result is the formation of a dense population. Bark beetles (Scolytidae) aggregate on suitable trees as a result of use of aggregation pheromones, but the ultimate purpose of the aggregation is for oviposition and breeding. Thus, functionally many of the aggregation pheromones are also used to stimulate oviposition upon the correct host plant. This point is mentioned later under the heading of 'plant odours', as there appears to be probable interaction between plant volatiles and pheromones connected with the oviposition of many phytophagous insects.

Alarm behaviour

This is characteristic of social Hymenoptera and Isoptera, and may be seen most dramatically when field workers disturb a nest of Paper Wasps (*Polistes* spp.) or arboreal ants in plantation trees. The wasps (and bees) produce alarm pheromones both when they sting and when gripping with their mandibles. The pheromone is released from glands in the stinging apparatus and from the mandibular glands, but apparently the worker can open the sting chamber and emit the pheromone without the necessity of stinging.

It has recently been demonstrated that aphids secrete alarm pheromones from their siphunculi when distressed. Recent work at Rothamsted has shown that a wild potato (*Solanum berthaultii*) produces a chemical mimic of this pheromone from special secretory hairs on the foliage which appears to repel aphids from its leaves.

Attractants

Initial experimental studies on female sex pheromones were conducted using live virgin females that had been laboratory-reared, or else a chemical extract was made from the abdomen tips of many young females and this was used instead of the live insects. It was soon apparent that these sex pheromones have considerable potential application in pest management programmes and so many organic chemists in government and industrial establishments started work in this field.

One approach was to carefully analyze the tiny quantities of natural pheromone produced by virgin females, and, when the chemical components were isolated and identified, to attempt to synthesize the same chemical compounds in the laboratory.

The second approach was to try and synthesize closely related chemical compounds which might possess the behavioural qualities of the natural pheromone, but were easier and cheaper to manufacture. In this way pheromone homologues and analogues have been produced commercially. A *pheromone homologue* is a very closely related compound, which differs only from the natural pheromone by chain lengthening or shortening following, for example, addition or removal of a methylene group. A *pheromone analogue* is a less-closely related compound that has major basic differences in structure, such as the change of a functional group or its position, for example an alcohol, ester or ketone.

The third approach was to use a vast range of organic chemicals, which it was thought might possibly function in a manner similar to sex pheromones, and to use them in laboratory and field trials in a purely empirical manner to see if they did possess such qualities. The organic chemicals that have been found to be successful in attracting certain male insects are collectively referred to as *sex attractants*. Obviously for monitoring purposes it does not matter how the chemical attracts the insects so long as it does attract them sufficiently well, and a great deal of research effort is being expended in this field at present. Sometimes these chemicals are termed *pheromone mimics*, for the obvious reason that they produce a similar reaction in the receiving male insect. 'Hexalure' is a chemical attractant produced commercially in the USA for use with Pink Bollworm on cotton, in a disruptive technique to prevent mating.

Recent work has demonstrated that many pheromone complexes are subjected to *synergism* in one way or another. In some cases it appears that some of the minor components have a synergistic effect on the major components or else on the pheromone complex as a whole. Sometimes the synergist may be a chemical released by the host plant; this may be of more importance in aggregation or oviposition behaviour, for example in scolytid infestations of forest trees various terpenoids are released by the injured tree which interact with the aggregation pheromones released by the beetles. Empirical chemical testing has discovered a number of synergists for use with sex pheromones that appreciably enhance their performance.

The sex pheromones of insects must, by their very nature, be quite specific to each species but some of the attractants have a very useful and much broader response, for example 'Cu-lure', developed initially for Melon Fly (*Dacus cucurbitae*), and methyl eugenol both attract all species of *Dacus* and some other fruit flies in addition, which makes these chemicals very useful for survey studies.

Sex attraction in Lepidoptera

Most of the work on sex pheromones and attraction has been done on the Lepidoptera, and the greatest potential for pheromones in pest management is in this group.

The 'calling' female moth emits her sex pheromones from the genital opening on the abdomen tip and the chemical complex is carried downwind as a plume. The odour plume is basically cone-shaped, but is flattened ventrally if the moth is close to the ground; the plume widens and the chemicals disperse as they are carried from the source. The shape of the plume is clearly controlled by wind speed and direction, the contours, and the presence of tall vegetation such as trees. Most virgin female moths 'call' at dusk or at night when there may be strong temperature gradients, or even inversions, over the ground, and these will obviously have effects on the spread of the pheromone.

The male moth responds to the pheromone by anemotaxis, in that it flies upwind in a zig-zag pattern. At first (assuming the male to be some distance from the female) the flight pattern of the male moth diverges from the plume of pheromone quite often, but as it approaches the female the pheromone concentration increases and the flight of the male moth becomes more direct.

The patterned response by a resting male moth to female sex pheromone can generally be described in half-a-dozen sequential stages, as follows:

(a) reception – antennal elevation or twitching,
(b) activation – wing fanning or fluttering,
(c) active flight,
(d) orientation to the source of pheromone – i.e. anemotaxis,
(e) alighting – landing in the immediate vicinity of the female moth,
(f) courtship – including gland extrusion and release of male pheromone,
(g) mating.

Thus it is clear that the behavioural response by a male moth to a 'calling' female is a complex sequential series of events and is not just a simple attraction.

The initial responses are made to a low concentration of pheromone, but the later events require an ever-increasing concentration of pheromone. It is now thought that the different components of the sex pheromone are responsible for different parts of the behaviour sequence. Thus, if in an experiment one minor component is missing, this will result in the behaviour sequence being broken, and the experimental results confusing.

With *Adoxophyes orana* it has been demonstrated that the female sex pheromone has two components and that there are three different types of chemoreceptors on the male

antennae (Den Otter, 1980). One type of sensillum reacts to the first component in electroantennagram studies, the second type reacts to the second component in the female pheromone, and it is suspected that the third type of sensillum may react to the male pheromone at close range, but this has not yet been demonstrated.

Insect feeding on plants

Insect feeding

The feeding process in animals involves different aspects, all of which have some importance in relation to control of pests. The main aspects include:

(a) Recognition of food
 (i) distant
 (ii) proximal
 (iii) contact
(b) Manipulation of food
(c) Ingestion

(a) Recognition of food

(i) *Distant*. This is usually (for most animals) a sight reaction to shape and colour; at what distance host/food recognition is achieved is probably very variable. With some birds of prey it can be up to a kilometre, but at the other extreme for mammals such as moles it is probably only a few centimetres. For many haematophagous Diptera, host/prey movement is very important for distant recognition, followed by heat radiation when closer; but these factors are scarcely applicable to plant hosts. With herbivorous insects long-range recognition is probably a combination of sight and smell. A recent review on this topic is by Prokopy & Owens (1983). Presumably with a large crop, odour recognition from a distance may be achieved; this must give some crop pests a distinct advantage over insects feeding on wild hosts in natural (mixed) vegetation.

Yellow coloration is certainly an attraction to many insects, and it is thought that this is basically because the young and very old leaves have more available foodstuffs in the tissues than the mature leaves: there would certainly be soluble sugars in such leaves as opposed to insoluble starch deposits, and apparently a higher than usual nitrogen content usually confers (in young leaves) a yellowish coloration. Blue is attractive to some Tsetse, but aphids are repelled by blue colours.

(ii) *Proximal*. At closer quarters sight may still be important, as some plants do have what appear to be quite definite recognition signals for searching insects (although most of these are connected with the need to attract pollinators). Scent recognition is presumably of prime importance, utilizing both natural volatile elements and also metabolic by-products.

(iii) *Contact* (host-plant testing). If the host plant looks and smells correct then the insect alights and contact is effected. The aura of the plant will then be reinforced or superseded by the taste; these stimuli being received through chemoreceptors on the foretarsi and the palpi of the mouthparts.

(b) Manipulation of food. This involves the cutting up of pieces of plant material by the mandibles, tasting them, and their manipulation by the various mouthpart structures into a position for ingestion. For sap-sucking insects this involves the insertion of the proboscis into the correct site for food ingestion, sometimes into the xylem vessels (Cercopidae, etc.), usually into phloem tubes (Aphididae, etc.), and sometimes just into mesophyll tissues or a ripening fruit.

(c) Ingestion. For insects with biting and chewing mouthparts the addition of saliva to the chewed fragments is important for lubrication to avoid damage to the oesophagus. The Hemiptera apparently all inject saliva and/or regurgitate stomach enzymes when feeding. Precisely why this is done with plants is not clear, but obviously with blood-sucking and predacious bugs their saliva contains an anti-coagulant which permits them to feed without the blood clotting in the proboscis. The predacious forms also practise external digestion of part of their prey in order to be able to render their food liquid enough to be imbibed through their proboscis. The injection of saliva and/or enzymes into the host plant when feeding is of importance agriculturally as the plant reacts to the presence of these alien substances by growth distortion, or necrosis of tissues.

Plant odours

Most plants release volatile odorous chemicals into the atmosphere (although the majority are undetectable by human sense) and phytophagous insects react to these chemical stimuli when locating host plants. Monophagous and oligophagous phytophagous insects usually react to specific volatile odorous chemicals in, and emitted from, the host plant. It is thought that polyphagous insects either have no olfactory chemical response, or else react to general plant chemicals. The olfactory chemoreceptors are mostly situated in the antennae, but in some Diptera they are located on the tarsi (feet).

It has very recently been demonstrated that very strong plant odours can inhibit sex pheromone reception; the interaction of plant odours and sex pheromones is thought to be complementary under natural conditions, so that mating is more likely to be successful on appropriate host plants, whereas the chances of mating taking place on inappropriate host plants are reduced. As this is a very recent discovery, as yet little work has been carried out, but future studies might well give rise to a greater understanding of the general phenomenon of host-specificity in phytophagous insects.

The chemical attractants in plants, when identified, are usually a mixture of many different compounds, for example, cruciferin in the brassicas is a complex mixture of glucosides, amines, and other chemicals. Biochemical research has shown that most of the more important volatile chemicals in plants are secondary metabolites.

Work at Wellesbourne (NVRS) has demonstrated that Cabbage Root Fly are clearly attracted to some of the volatile chemical components released by plants of the Cruciferae, and some stimulate increased egg-laying. It was shown that gravid females could move at least 24 m upwind to a brassica crop in response to the odour stream. Volatile hydrolysis products are constantly released, at low concentrations, from Cruciferae during normal growth and development, resulting from damage or death of cells, and by the endogenous enzyme system. More than 23 different compounds were obtained from cultivated crucifers at NVRS (Cole, 1980); the actual component constitution varied with the species, the age and stage of development of the plants. Only a few of the 23 compounds actually elicited a response from the flies when used in isolation. The overall situation with regard to plant production of volatile chemicals is clearly complicated, but a great deal of research effort is being expended on this subject worldwide, and gradual elucidation is to be expected. Other relevant publications include Wallbank & Wheatley (1979), Ellis, Cole, Crisp & Hardman (1980), and Crowson (1981). An especially useful book is *Insect Herbivory* by Hodkinson & Hughes (1982).

Ferns as a group are little attacked by insects, and this is thought to be because they contain considerable quantities of repellent/toxic chemicals such as ecdysones, glycosides, phenols, sesquiterpenes, tannins, thiaminase, etc.; the group is ancient and has presumably been grazed extensively, particularly in the days before the evolution of the flowering plants. One striking feature in ferns is that the chemical production is at a peak very early in the growing season so that the youngest fronds are usually the most toxic as well as containing the most available protein.

Studies at Rothamsted have shown that a type of wild potato (*Solanum berthaultii*) from Peru, has two types of 'hairs' (trichomes) on its foliage: one type is short with a sticky head, and the secretion can trap insects on the leaves and stems by adhesion; the other hairs are longer and secrete fluid containing (E)-B farnesene, which is the main ingredient of the alarm pheromone in most species of Aphididae. Experiments showed that *Myzus persicae* aphids were reluctant to invade the foliage of this plant.

In addition to the attractive odours, plants also produce volatile chemicals that function as repellents (from a distance) or feeding inhibitors (at close range), and these form part of the plant defence mechanism against insect attack.

Plant resistance to insect feeding

A very recent and exciting development in insect/plant relationships is the concept of rapidly induced anti-insect defences in plants; this is mentioned at the end of this section. It has even been postulated that there can be communication between adjacent trees through airborne chemicals, so that neighbouring trees increase their defences before being attacked by the insects. However, it should be stressed that this line of research is very much in its infancy and the available data may have alternative interpretation (see Fowler & Lawton, 1984).

The basic resistance exhibited by plants to insect attack is partly physical and partly chemical. The physical properties include:

(a) Thickened cuticle
(b) 'Hairy' epidermis (trichomes may be hooked, secretory, or just physically close together)
(c) Hardening of tissues by general sclerenchymatization
(d) Increasing the extent of natural silica deposits in the tissues
(e) Spiny leaf margins (e.g. holly) may deter some leaf-margin eaters (the thorns and spines developed presumably to deter vertebrate grazers and browsers are not effective against insects; in fact some insects mine spines!)

The chemical defences include:

(a) Absence of specific attractants or feeding stimulants that would otherwise normally be present
(b) Presence of repellent odours to deter insects from alighting on the plant
(c) Presence of distasteful or poisonous chemicals in the tissues to deter feeding
(d) Absence of certain chemicals (often amino acids) required for normal development of the immature insects
(e) Presence of chemicals that mimic insect alarm pheromones, for example the wild potato already mentioned and the aphid alarm pheromone mimic

The major chemical repellents in plants seem to be terpenes, tannins and various alkaloids. Tannins are mostly found in horsetails, ferns, gymnosperms, and some angiosperms, and they are quite antibiotic to many pathogens. Alkaloids are mostly found in angiosperms and are thought to be of more recent origin. It is thought that tannins were developed initially in the process of evolution as a deterrent to grazing reptiles, and the alkaloids similarly evolved as a protective mechanism in angiosperms to repel grazing mammals. It seems unlikely that the Insecta were at all involved in the evolution of feeding repellents in plants, although these may now be of considerable importance with respect to phytophagous insect feeding behaviour. The insect biotypes that come to feed on 'repellent' varieties of crop plants (and other plants) usually develop biochemical detoxification mechanisms, so that the poisonous compounds are broken down into non-toxic degradation products.

It has been suggested that 'dominant' (termed 'apparent') species of plants have chemical defences that tend to cause digestive difficulties and retard development of insects feeding on their foliage, rather than actually causing death

(see Crowson, 1981; chapter 18); and also that the pests of these plants tend to be polyphagous (and possibly the more ancient) species. Good examples of such dominant plants include the oaks (*Quercus* spp.) and beech (*Fagus* spp.); their main defences against insect herbivores appear to be a combination of sclerification of the leaf tissues and accumulation of tannins. After about a week or two from leaf-unfolding, the young leaves become quite inimical to the insects; larval development slows, mortality increases, fewer eggs are laid, etc. Many insects have adjusted their life cycles so that they are able to feed on the young leaves during the short period of time while they are palatable. The less-dominant plants (termed 'unapparent'), which are usually the more recently evolved, tend to be the ones to develop actual poisons (alkaloids, etc.) as their chemical defence.

It is now clearly established through recent research that some plants respond to insect feeding damage by active production of deterrent chemicals, so that their final concentration in the leaf tissues is considerably greater than before. In some cases the whole tree produces more chemicals, not just the damaged leaves. The entire subject of insect/plant relationships has recently been evoking a great deal of interest and much has been published of late.

As mentioned at the start of this section, it has been said that insect-injured plants emit volatile chemicals that stimulate neighbouring trees to produce defensive chemicals irrespective of whether they are attacked or not. But the data at present are not really conclusive, and are usually open to other interpretation. It might be expected that the levels of chemical secreted into the air would be too low a concentration to elicit such a response from a receiving tree.

Food sources for adult insects

When considering the subject of insect pest feeding, it is invariably assumed that it is the pest stage of the insect feeding on the cultivated plant. With groups such as Orthoptera, Hemiptera, and some Coleoptera (e.g. Chrysomelinae) both adult and immature insects are found side-by-side on the crop and both cause damage (often identical, sometimes different). However, within the Diptera and Lepidoptera it is the larval stages that are agricultural pests; the adults are free-living and with a very few exceptions (such as fruit-piercing moths) not crop pests, although some females may cause damage to the plants when ovipositing. Most of these adult insects (females anyway) require food prior to ovulation or egg development, and in temperate regions the spring/summer emergence of adults is often closely synchronized with the flowering of various local wild herbs and shrubs.

A striking example of this dependence upon local vegetation is seen with many flies (Muscidae, Anthomyiidae, Psilidae, etc.) in Europe where the newly emerged adults congregate and feed upon the flowers of wild Umbelliferae common on headlands and in hedgerows. The most abundant and widespread species of Umbelliferae concerned as nectar sources as follows:

Common name	*Scientific name*	*Flowering period*
Cow Parsley	*Anthriscus sylvestris*	April–June
Hemlock	*Conium maculatum*	June–July
Hogweed	*Heracleum sphondylium*	June–September
Upright Hedge Parsley	*Torilus japonica*	July–August
Wild Angelica	*Angelica sylvestris*	July–September
Fennel	*Foeniculum vulgare*	August–September

One reason for the importance of this group, apart from their widespread distribution, is the sequential flowering periods which result in a continuous flower availability in hedgerows from early April until the end of September, or even into October. Thus there is nectar available for each successive generation of adult flies as they emerge.

For many groups of insects there is no obvious link with a particular group of nectar-producing plants upon which they are dependent. Many moths are quite opportunistic in their feeding and will take nectar from many different sources. The early spring in Europe is characterized by a paucity of flowers: only a small number of plants have flowers at this time so natural sources of nectar for early-emerging flies (and moths) in April are quite limited. Later, by June and July, the countryside is a profusion of flowers, and nectar sources are numerous.

Adult insects that emerge and oviposit over the winter period, such as Winter Moth and other hibernal Geometridae, use their fat body for nutrients and they lay their eggs without feeding at all; but, of course, their pupal period was relatively brief.

Many of the muscoid flies, whose maggots attack vegetables in the soil, or cereal seedlings, feed predominantly on the flowers of the wild Umbelliferae listed above, and in most cases it appears that the nectar feed is necessary for egg development. These flies typically emerge from overwintering pupae in April, in the UK; they include Cabbage Root Fly, Onion Fly, Bean Seed Fly, and Carrot Fly amongst others.

Knowledge as to the feeding requirements/preferences of the adult insects can be ecological information of great use in survey studies and in population monitoring, and might on occasion be used for an adult insect control programme. This would be a line of research that might be profitably pursued for a number of important crop pests.

Abundance and richness of insect (arthropod) faunas on host plants

Another aspect of insect-plant relationships receiving attention recently is the analysis of the factors seemingly responsible for the abundance (numbers of individuals of each species) and richness (numbers of different species) of the insect fauna (including phytophagous mites) on trees. Most of the published studies refer to indigenous trees, but the basic ecological concepts involved should have application to the study of long-term orchard and plantation crops and

their pests. Clearly these studies are, at present, confined to more or less permanent hosts such as trees, for the study of annual plants would present additional complications reflecting their ephemeral nature.

In a recent paper by Kennedy & Southwood (1984) (which includes a comprehensive bibliography) they investigated the following factors with reference to insects on British trees: host-tree abundance, time, taxonomic isolation, tree height, leaf size, and two more nebulous characters termed 'coniferousness' and 'deciduousness'. The most important factors were the first two. *Host-tree abundance* refers to the overall area of habitat available for colonization; a larger area is also likely to provide more different microhabitats and thus a wider range of niches for a larger group of associated species. *Time* refers to the evolutionary age of the tree species, and would seem to be positively correlatable to the species richness of the insect community, although there has been some controversy on this point. Of the other five factors considered by Kennedy & Southwood all, with the exception of 'coniferousness', apparently made significant contributions to the present recorded diversity.

Banerjee (1981) made an analysis of tea pest species and reported that time (measured as the age of the plantation) was the major factor in relation to pest recruitment; pest diversity reaching maximum at a plantation age of about 35 years. With other tropical plantation crops it seems that other factors may be more important in relation to pest diversity.

A number of useful papers on insect–plant relationships are presented in the Royal Entomological Society of London, Symposium Number Six, edited by H.F. van Emden (1972).

Insect (pest) distributions

The distribution of animals and plants throughout the world is controlled by many different factors. With cultivated plants clearly the most dominant factor has been the deliberate transport by man. For insects and other animals the evolutionary history of the area is of importance, but probably the overriding factor is the climate. Of the climatic factors temperature is the most important (and most easily measured). As insects are poikilothermic they have only a little influence over their body temperature over which the various bodily functions operate most efficiently, and they have a heat death point and a cold death point at which they die. From the point of view of distribution globally the cold death point is the most important, and the insects can be divided into three main groups on this basis, as follows:

(a) Tropical insects – cold death point circa 10–15°C
(b) Temperate insects – cold death point at 0°C (death because of ice crystal formation in the cells/tissues)
(c) Boreal (Arctic) insects – death point well below 0°C (−20–30°C often); body fluids supercool and freeze to glass

A few well-known species are clearly *eurythermal* and are able to have a worldwide distribution as they can function over a wide range of ambient temperatures. Some others are *stenothermal* and only thrive in a narrow range of temperatures, either low, high or intermediate.

Pest organisms are species renowned for their biologically aggressive and opportunist nature in relation to hosts, and on the whole their distribution tends to be ever-increasing to the limits of suitable environmental conditions; these limits are often climatic.

Knowing the *optimum* conditions of temperature and relative humidity for the development/activity of an insect species, and its preferred range of conditions, it is possible to plot a *climatograph* with different areas of suitability/abundance for the species. This is sometimes used in making prediction assessment of the climatic suitability of an area for an outbreak/invasion of a particular pest; knowing the zones of suitability in regard to climate for the pest, if the monthly means of temperature and humidity are plotted on to the graph a polygonal diagram results, and the placement of the diagram indicates the likelihood of climatic suitability. In fig. 4 is shown the climatograph for the Medfly (*Ceratitis capitata*) in relation to (A) Orlando, Florida, (B) Naples, Italy and (C) Ankara, Turkey (from Edwards & Heath, 1964). If temperature and rainfall are used as criteria the diagram is called a *hythergraph*.

After extensive laboratory studies and field observations it is possible to designate three fairly distinct zones of abundance for each insect (pest) species, as follows.

(A) (Endemic) zone of natural abundance. Here the pest species is always present, often in large numbers, and regularly breeding. Environmental conditions are generally optimal for this species, and in this zone the species is regularly a pest of some importance.

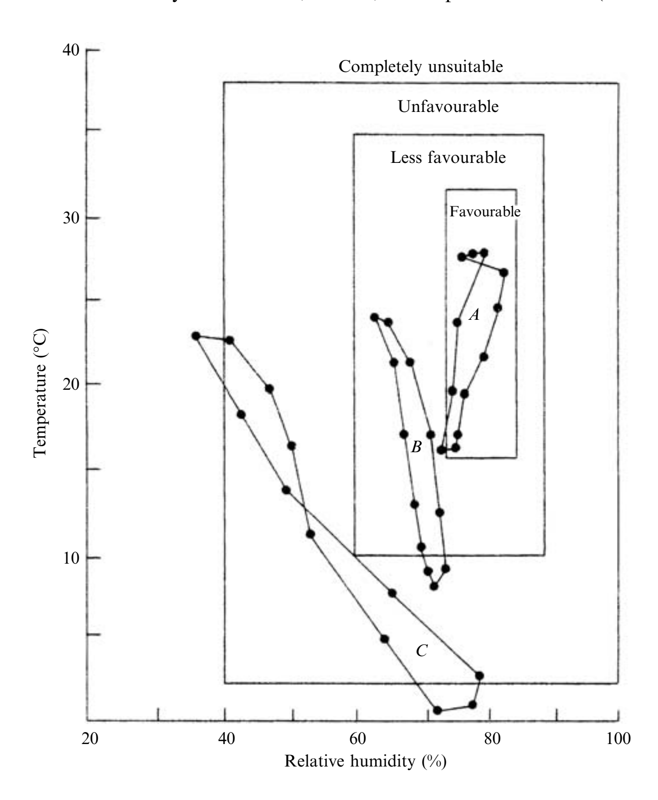
(B) Zone of occasional abundance. Here the environmental conditions are either less suitable (i.e. drier, cooler, etc.) or else with pronounced variation (often seasonal), having periods of suitable conditions alternating with unsuitable. The population is kept low by the overall climatic conditions; some breeding does occur, but only occasionally does the population rise to pest proportions. Sometimes climatic conditions are sufficiently severe to destroy the entire population, which then has to be re-established by dispersal from the endemic zone.

(C) Zone of possible abundance. This is essentially a zone into which adult insects spread (disperse) from zones (A) and (B). The immigrant population may survive for a time, and may actually be a pest for a while, until changing climate destroys the organisms. Breeding in this location is rare, but permitted occasionally by a period of mild weather. Occupation of this zone is strictly ephemeral (short-lived).

In fig. 4, the three boxes on the graph (A, B, C) could be regarded as corresponding to the three natural zones of abundance.

The basic nature of an insect population is to increase, and unless it is controlled by changing climate, heavy

Fig. 4. Climatograph for the Mediterranean Fruit Fly. A = Orlando, Florida; B = Naples: C = Ankara (from Edwards & Heath, 1964).



predation or parasitism, or artificial control measures (i.e. insecticide spraying) there is usually dispersal of part of the population to alleviate the competition pressure for food or other limited resources. Thus many pest species increase in numbers in zone (A), and when the population density is high some disperse into zones (B) and (C) from time to time. These three zones are not necessarily constant in their demarcation, depending in part upon the nature of the limiting factors controlling the distribution of the pest organism. Often the main limiting factor is available food, and if the host crop becomes more widely cultivated then many pests may follow the crop into the new regions.

The dispersal success of a pest organism depends upon several factors, including the effectiveness of the precise method of dispersal (e.g. insect flight, wind-carried fungal spores, transport on agricultural produce, etc.) and the adaptability of the pest. Many of the most successful pests have a eurythermal physiology and a polyphagous diet.

As an example of the interaction between temperature and relative humidity the diagram made by Uvarov (1931) for the Cotton Boll Weevil can be used (fig. 5). It may be generally regarded that conditions optimal for rate of development are also optimal for the whole organism and its general well-being. Strictly speaking this may not be true, for in some species the different physiological processes have slightly different optima.

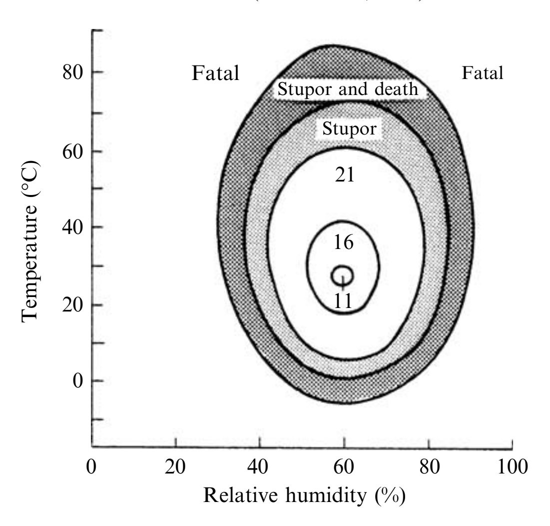
Changing distributions

In the past many of the major changes in the distribution of a pest species were made through human agency, for example the Gypsy Moth or Colorado Beetle, either intentionally or accidentally. But occasionally an animal drastically increases its distributional range under its own powers of dispersal; the reason for the spread is generally not understood. These sudden changes are usually termed *invasions* so far as the new countries are concerned. There have been two quite recent and interesting invasions in the UK. Firstly, the Collared Dove (*Streptopelia decaocto*), an Asiatic species, normally resident (i.e. non-migratory), which invaded Europe through Turkey early this century and was first recorded in the UK in 1951 in East Anglia. This is now widespread and locally abundant, and has even bred in Iceland. It is somewhat urban in habits and regarded as a pest species by chicken rearers as it takes grain fed to the chickens in open runs. A recent insect pest to invade the UK is the American Lupin Aphid (*Macrosiphum albifrons*), first recorded in West London in 1981. It withstood the statutory eradication measures that were immediately implemented, and is now abundant and widespread in England and Wales as far north as Yorkshire. This pest is confined to lupins, so far as is known, and infested plants often die, unless control measures are applied. In both the UK and in many parts of Europe there is recent interest in lupins both as a break crop

in cereals, and some annual species are grown for their seeds which have a protein content higher than soybean. Some perennial species are also being used very successfully as pioneer colonizers on open-cast mining reclamation sites. Thus the Lupin Aphid, which first seemed to be only serious to gardeners in destroying their flowers, now appears to have much more serious economic significance. At present it has not been recorded from Europe.

Pests that are *native*, or *endemic*, to a region are referred to as *autochthonous*, the implication being that they have evolved locally. Species now found locally, but which are thought to have originated elsewhere, are termed *allochthonous*; they are usually immigrants of one type or another.

Fig. 5. Time of development of the Cotton Boll Weevil (in days) in relation to two climatic factors (after Uvarov, 1931).



Pest distribution

When considering the different insect and mite pests in an area or on a crop it is sometimes necessary to regard them in a broader context of their overall distribution. To elucidate the terminology used in biogeography, fig. 6 shows a map of the World with the generally accepted major biogeographical subdivisions.

Zoogeographically a somewhat different terminology is used, as shown in fig. 7.

Dispersal

This is the natural spread of part of a population away from its source (origin) at a time of high population density. With birds and mammals, the dispersal is often partly to seek new territories, and sometimes it is a population survival mechanism to ensure that, on dispersal of the first brood, the parents find sufficient food in their territory to raise a second brood of offspring. With insects, dispersal sometimes appears to be obviously in response to dwindling food supplies, or a reduction in the availability of suitable food (such as progressive drying of leaves, etc.), and sometimes it appears more as a behavioural quirk which coincides with certain weather conditions. The overall effect is clearly beneficial from the point of view of survival of the species. Dispersal appears to be very important for the overall survival of the species as it enables diminished populations to be replenished, and the spread of genetic material through the entire population is advantageous. Also newly available habitats (such as new agricultural crops) can be colonized. In the same way that all animal and plant populations have

Fig. 6. General geographical/biological subdivisions of the World.

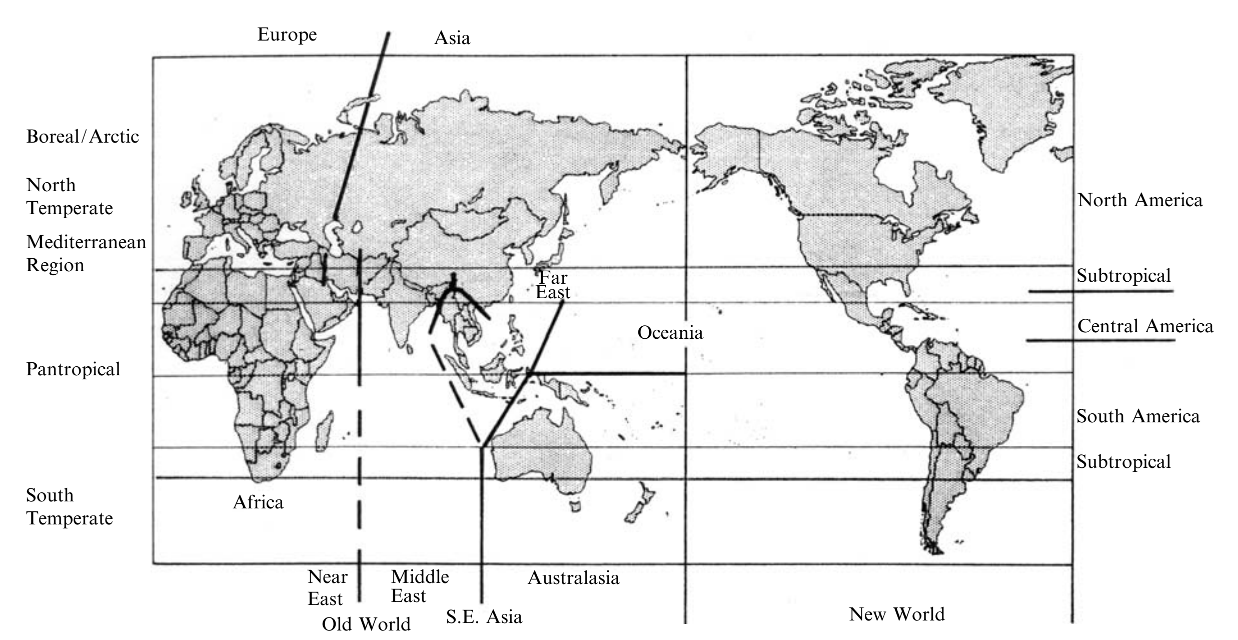
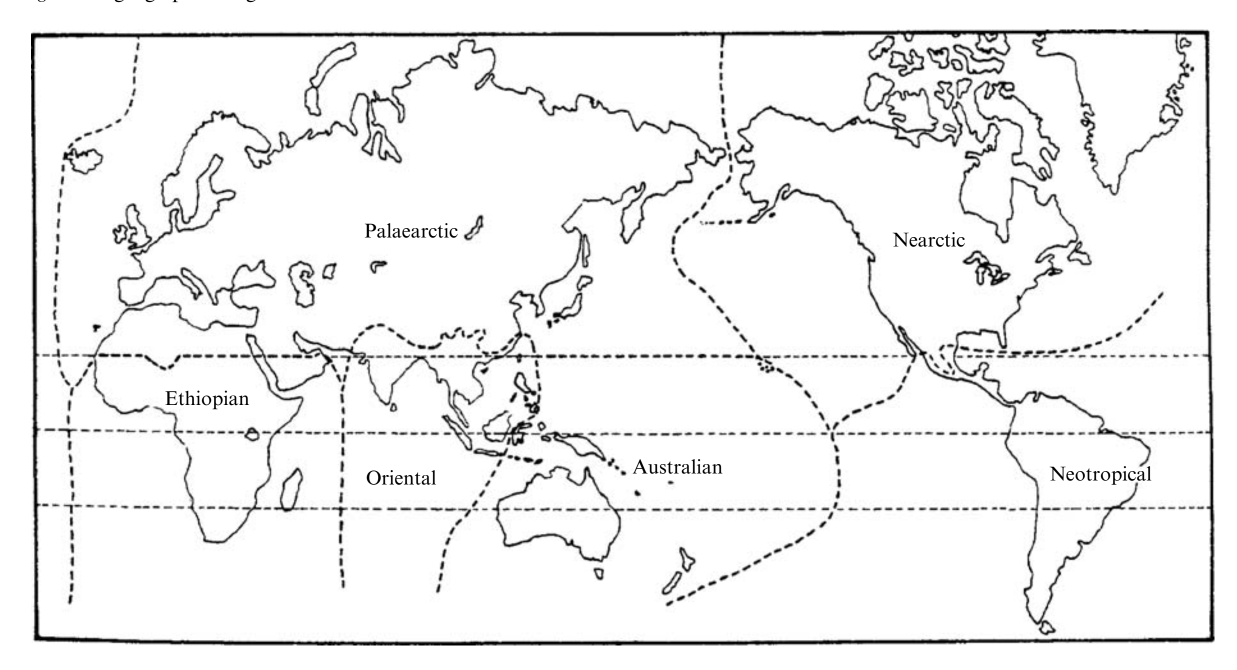


Fig. 7. Zoogeographical regions of the World.



an innate tendency to increase, they display a similar innate tendency to dispersal.

Migration

The movement of animal populations, or individuals, from one area to another on a larger scale than merely a local dispersal, can be defined in three different ways.

(a) Immigration – This is the movement of animals into a region.
(b) Emigration – This is the movement of animals out of a region.
(c) Migration – In the strict sense this applies to a definite double journey, firstly out of one region to another, and then the return to the original region. In the literature the term migration is sometimes incorrectly used to denote just a lengthy dispersal movement. It should be stressed that sometimes it is not clear to what extent a return movement occurs when pest migrations are discussed.

Flying birds, and migratory bats, are clearly in control of their direction of dispersal, although some species appear to prefer to fly into prevailing wind systems, whereas others apparently fly downwind for long distances. Most insects are small in size, and recent research does indicate that even with locusts, which are of moderate size, most movements are completely controlled by prevailing winds. It appears that the insects use their wings primarily to remain in the air and they are then carried quite passively by the wind or air currents to wherever the wind blows; when they stop flying they lose their buoyancy and descend. This is the situation for many long-distance dispersals; local dispersal and food/mate seeking is clearly an active procedure under individual control by the insect(s) concerned.

An interesting short review, titled *Dispersal and movement of insect pests* was published recently (Stinner *et al*., 1983).

Immigration is the movement of a pest population into an area from elsewhere, and in certain parts of the world is a very important source of major pests. In most of the tropics there is little insect migration (apart from locusts) because of the general stability of climate. Migration is typically an animal phenomenon of the colder parts of the world, where animals move away from northern areas after the short warm summer, and before the onset of the long cold winter. There are some tropical migrations, including the spectacular ungulate migrations of eastern Africa, where animals move to new food sources away from arid areas suffering from their annual dry season, they are basically following seasonal rains and the new grass growth that is promoted across part of the continent.

Animal migrations and dispersal movements are natural phenomena characteristic of all phyla in the animal kingdom and many species now regarded as pests will have generally dispersed during the millenia from their endemic areas (areas of origin). This innate tendency will still be present in all animal populations, but in some cases it operates slowly and may not be at all obvious. Flying insects can effect their own dispersal, influenced by winds and air currents of course. Some of the more novel means of dispersal include riding on floating flotsam (for rats, insects etc.), concealment in the feathers of migrating birds, and aerial transport by typhoon and hurricane. Migration and natural succession was clearly demonstrated on the island of Krakatoa after its total devastation by a volcanic eruption.

Locusts and armyworms (*Spodoptera* spp.) are migratory tropical species of considerable economic importance; they breed in areas of hazardous climate which compels them to disperse on their sometimes lengthy journeys.

The Brown Planthopper of Rice (BPH) (*Nilaparvata lugens*) has recently become established as a major pest of rice in Japan through its migratory behaviour. The climate of S. Japan (Kyushu) is sub-tropical or tropical in the summer, but the winter is cold with snow and ice and the BPH cannot survive the winter. The White-backed Planthopper (*Sogatella furcifera*) is likewise an annual migrant into Japan. These planthoppers (Delphacidae) live along the coastal regions of E. Asia (and elsewhere in India and S.E. Asia) and each spring they migrate northwards, usually entering Kyushu in Japan in the period mid-June to mid-July when they are caught in wind traps along the coast. They then breed on the rice crops and usually have four generations each summer in Japan before dying out in the cooler weather of the autumn after harvest.

Some of the countries most affected by regular pest migrations include Canada, Japan, North China, Fennoscandia, and to a lesser extent the UK. In Canada, particularly, there is quite a large number of insect pests that cannot survive the very cold winter; they arrive in early summer from the USA and breed during the hot Canadian summer/early autumn and then die later in the fall when temperatures plummet.

Pollination

The value of insect pollination of crops to man is really inestimable, although the annual yield of insect-pollinated crops in the USA has been estimated to be in the region of US $5000 million (at present values).

The crops pollinated by insects (entomophilous) include top fruit (e.g. citrus, apple, pear, peach, plum, cherry, almond, mango); bush and cane fruits (e.g. currants, raspberry, blackberry, gooseberry); ground fruit (e.g. strawberry); some Leguminosae (e.g. pulses, clovers); all Cruciferae (brassicas and other vegetables); other vegetables such as Cucurbitaceae and onions; cotton, cocoa, tea, some coffees; most flowers and some trees (e.g. lime).

The crops that are anemophilous (wind-pollinated) are mostly the Gramineae (cereals and sugar-cane), and many trees, particularly the Gymnospermae (pines, spruces and other conifers). A few crop plants are partly entomophilous and partly anemophilous, such as beet, spinach, carrot, parsnip, white mustard, charlock and chrysanthemum. With a surprisingly large number of crops there is apparently uncertainty as to the precise manner of natural fertilization. Some crops are grown in cultivated clones with fruit set by parthenocarpy (e.g. banana, and Smyrna fig), and others are propagated vegetatively like sugarcane and potato. Some crops are self-pollinating, such as *Coffea arabica*, pea, groundnut, some beans and many Solanaceae, but apparently sometimes cross-pollination by insects is effected.

One result of widespread use of chemical insecticides has been the great reduction of insect pollinator populations (mostly bees) in many parts of the world, and at the present time many crops are grown under conditions of inadequate pollination. However, for some crops which are at least partially self-pollinating the precise value of increased insect pollination is not known (Free & Williams, 1977). As mentioned later (page 62), some crops typically over-produce flowers and fruit so increased pollination of these crops may be of little value; but it does seem quite likely that many crops are now suffering from under-pollination. An example of the difference in yield that can be achieved by increased pollination in some crops was shown on red clover in Ohio (USA) where the average yield reported was about 0.1 m^3/ha of seed; after an increase in the local bee population the field yield rose to about 0.4 m^3/ha, and when a plot was enclosed and subjected to maximum pollination by bees the yield was raised to 1.1 m^3/ha.

Bee destruction in Japan has been serious since World War II due to the very intensive nature of agriculture there, and in some orchards, by 1980, growers had to resort to hand-pollination – both time-consuming and labour-expensive. It had been estimated that about 25% of labour-time in fruit orchards in Japan was spent on pollination of the crop. An interesting development in Japan has been to use mason bees (in particular *Osmia cornifrons*) in fruit orchards for pollination. Artificial nest sites (usually consisting of small bundles of open canes or narrow tubes, about 5–6 mm diameter) are manufactured and situated in suitable sheltered locations in the orchards, often under the eaves of the house and buildings. These sites are readily colonized by the mason bees. Research has shown the *Osmia* bees to be good pollinators; they forage in Japan from 08.00 h to 18.00 h daily, visiting some 15 flowers per minute. A local population of 500–600 bees per hectare will give adequate pollination without recourse to outside pollinators, and there will be a 50% fruit-set within 65 m of the nest site (Maeta & Kitamura, 1980).

The main groups of insects responsible for flower pollination are:

(a) Hymenoptera
  Apidae – Honey Bee (*Apis mellifera*), cosmopolitan
  – Other Bees (*Apis* spp.), pantropical
  – Bumble Bees (*Bombus* spp.), native to the Holarctic only (now in New Zealand)
  Megachilidae – Leaf-cutting Bees (*Megachile* spp.)
  – Mason Bees (*Osmia* spp.)

(b) Diptera
  Syrphidae – Hover Flies
  Muscidae – House Fly, Bluebottles, etc.

Some Lepidoptera (butterflies and moths) may be of importance, but mostly for ornamentals with flowers having a long tubular corolla. A few beetles and some thrips pollinate some crops, and a few somewhat bizarre tropical plants (e.g. orchids) are pollinated by humming-birds or bats.

The most important wild pollinators are probably bumble bees and flies, but *Bombus* is mainly Holarctic in

distribution. In the tropics, honey bees, Megachilidae and flies are probably the most important pollinators, but flies (Muscidae) can only pollinate the open-type flowers such as in the Cruciferae. In the cooler temperate regions *Apis mellifera* is domesticated and kept in hives which are easily handled and may be transported to orchards specifically for crop pollination. In the tropics however *Apis mellifera*, although domesticated and kept in 'hives', also occurs widely as wild colonies nesting in hollow trees, etc.

A fairly recent spectacular crop pollination success was made by C.A.B. International (1982). Oil Palm, native to West Africa, has been grown in plantations in Sumatra and Malaya since about 1930, and now is planted throughout S.E. Asia. But here the natural pollination was inadeuate and yields were low. To compensate the growers had to resort to hand pollination with an annual labour bill of about US $11 million. In 1978 C.A.B.I. sent entomologists to West Africa and they discovered a complex of pollinators of which weevils of the genus *Elaeidobius* appeared to be the most important. *E. Kamerunicus* was imported into Peninsular Malaya and is now widely successfully pollinating the oil palms with a consistent yield increase of about 20% and no need for hand pollination - making an overall annual saving of some US $115 million.

After the early catastrophes, when insecticide spraying in orchards and crops in flower resulted in large-scale bee destruction, most chemical companies are now including toxicity testing against bees as part of their regular pesticide screening programmes, and in the UK there are elaborate arrangements made to ensure that apiarists (bee-keepers) are warned before any major local insecticide applications are made. Also care is taken to avoid spraying particular crops in flower, so that bumble bee populations are safeguarded. In the tropics, however, there is seldom any warning given prior to spraying, but in these regions the majority of bees are wild anyway.

In the UK work on plant pollination is being conducted at Rothamsted Experimental Station, Herts., and from a bibliographical point of view by the International Bee Research Association (for example see Crane & Walker, 1983). An interesting review paper is by Kevan & Baker (1983).

3 *Principles of pest control*

Definition of the term 'pest'

Before contemplating taking any control measures against an insect species in a crop, the species must be correctly identified; then, presuming its biology is known, it should be clearly established that the species in this particular context is a pest, and that it could be profitable to attempt population control.

In this section the various terms used to describe pests are defined. It should be noted that some terms are more or less synonymous, but they are all well established in the literature. For example a *major* pest is very often a *serious* pest, and all *economic* pests are serious.

Pest. The definition of a pest can be very subjective, varying according to many criteria; but in the widest sense any animal (or plant) causing harm or damage to man, his animals, his crops or possessions, even if just causing annoyance, qualifies for the term pest. From an agricultural point of view, an animal or plant out of context is regarded as a pest (individually) even though it may not belong to a pest species. Thus a deer on a farm is a pest, but next-door in a game park it is not, and is in fact a valuable national asset there. Similarly, volunteer cabbage plants growing in a field with onions have to be regarded as 'weed' pests.

Many insects belong to generally accepted *pest species*, as listed in chapter 10, but individual populations are not necessarily always pests; that is, of course, not necessarily *economic pests*.

As pointed out by Norton & Conway (in Cherret & Sagar, 1977), we are often somewhat over-preoccupied at the present time with the state of the 'pest' population, whereas probably the most important aspect of a pest species is the damage (or illness) caused by the pest and the value placed upon these consequences by human society.

Economic pest. On an agricultural basis, we are concerned when the crop damage caused by insects leads to a loss in yield or quality, resulting in a loss of profits by the farmer. When the yield loss reaches certain proportions the pest can be defined as an economic pest. Clearly the value of the crop is of paramount importance in this case, and it is difficult to generalize, but as a general guide for most crops it is agreed that most species reach *pest status* when there is a 5–10% loss in yield. Obviously a loss of 10% of the plant stand in a cereal or rape field (note that this is not the same as a 10% loss in yield!) is not particularly serious, whereas the loss of a single mature tree of *Citrus*, apple or peach is important.

Economic damage. This is the amount of damage done to a crop that will financially justify the cost of taking artificial control measures, and will clearly vary from crop to crop according to its basic value, the actual market value at the time and other factors. In practice, many peasant farmers engaged in subsistence farming feel that they cannot justify use of pesticides at all.

Economic injury level (EIL). This is the lowest population density that will cause economic damage, and will vary between crops, seasons and areas. But it is of basic agricultural importance that it is known for all the major crops in an area.

Economic threshold. It is desirable that control measures be taken to prevent a pest population from actually causing economic injury. So the economic threshold (Stern *et al.*, 1959) is the population density of an increasing pest population, at which control measures should be started to prevent the population from reaching the economic injury level (see fig. 2).

Pest complex. The normal situation in a field or plantation crop is that it will be attacked by a number of insects, mites, birds and mammals, nematodes and pathogens which together form a complicated interacting *pest complex*. The control of a pest complex is complicated and requires careful assessment, especially as to which are the *key pests*, and careful integration of the several different methods of control which may be required. This, of course, makes the process of evaluation difficult, and generally, in the past, much money was wasted on uneconomic pest control, either through carelessness or lack of knowledge.

Pest spectrum. This is the total range of different types and species of pests recorded attacking any particular crop, and especially of concern in one particular area. The total number of insects (and mites) recorded from the major crop species are considerable; these records, incidentally, are of insects feeding or egg-laying on the plant, and do not include casual observations when the insect might just be resting, or when, for example, caterpillars have crawled up on to the plant just to pupate (e.g. Large White Butterfly). Simmonds & Greathead (in Cherrett & Sagar, 1977) listed the numbers of pest species, on a world basis, recorded from sugarcane as 1300, cotton 1360, coffee 838, and cocoa 1400. Fortunately, for the practising entomologist, and the farmers, these numbers reflect the situation globally and many of these pests are restricted geographically to one part of the world. For example, wherever apple is grown it will be attacked by a tortricid complex (Lep., Tortricoidea) but the actual species differ from region to region. Only a few major pests are completely cosmopolitan (e.g. *Myzus persicae*, *Agrotis ipsilon*) or pantropical (e.g. *Maruca testulalis*) in distribution (in point of fact, their widespread distribution is one reason for their being regarded as major pests).

Pest load. This is the actual (total) number of different species (and numbers of individuals) of pests found on either a crop or an individual plant at any one time, and, as already mentioned, this would usually be a pest complex, but could also be a monospecific population, although this would be rare.

Key pests. In any one local pest complex it is usually possible to single out one or two major pests that are the most important; these are defined as key pests, and are usually perennial and dominate control practices. A single crop may have one or more key pests, which may or may not vary between areas and between seasons. It is of course necessary to establish economic thresholds for these key pests in order to be certain when to apply control measures, for it has been often observed that the mere presence of a few individuals of a key pest species in a crop may cause undue alarm and lead to unnecessary pesticide treatment. Key pests owe their status to several factors, including their usually high reproductive potential, and the type of damage they inflict on the host plant (e.g. Codling Moth on apple; Boll Weevil on cotton).

Serious pest. This is a species that is both a major pest and an economic pest of particular importance, being very damaging and causing considerable harm to the crop plants and a large loss in yield. It almost invariably occurs in large numbers.

Major pest. In this book these are the species of insects and mites that are either serious pests of a crop (or crops) in a restricted locality, or are economic pests over a large part of the distributional range of the crop plant(s). Thus the species here regarded as major pests usually require controlling over a large part of their distributional (geographical) range, most of the time. As mentioned in chapter 1 however, some species of insects have been included as 'major pests' in this book because of their widespread and frequent occurrence, biological interest, wide range of host plants, or other aspects of academic interest. In any one crop, in one location, at one time, there is usually only a rather small number (say 4–8) of major pests in the complex that actually require controlling. For example, although the pest spectrum for cotton worldwide is 1360 species, on any one cotton crop there will probably only be about five species requiring population control. Usually for most crops in most localities the major pest species remain fairly constant from year to year, but several entomologists have commented recently that in some areas they have observed that the major pest species complex has been gradually changing over a long period of time. Soehardjan (1980) reported that in Indonesia the 8–10 major pests of rice have largely changed over the period of time 1929–79, although there are some differences within different parts of the island of Java. As mentioned already, the Brown Planthopper (BPH) of rice has risen in 10 years from obscurity to becoming the most serious pest of rice in most parts of Asia. And it is reported from IRRI that there are now two new major rice pests in tropical Asia (Pathak, 1980): the Sugarcane Leafhopper and Rusty Plum Aphid. So over a period of some 10–50 years it is expected that the complement of major pests for a crop may change. It must be remembered that evolution continues all the time, though it is not often obvious, and that in an artificial environment, such as agriculture, it can be expected that evolution will be accelerated.

Minor pests. These are the species that are recorded feeding or ovipositing on the crop plant(s) but usually do not inflict damage of economic importance; often their effect on the plant is indiscernible. They may be confined to particular crop plants or may prefer other plants as hosts. Many (but not all) pests listed as minor pests are potentially major pests (viz. BPH of rice). Many species that are major pests of one crop will occur in a minor capacity on other crops. And sometimes a major pest of a particular crop in one part of the world (e.g. Europe) will be a minor pest on the same crop in a different part (e.g. Australia or the New World).

Potential pest. This term is used occasionally in the literature and refers to a minor pest species that could become a major pest following some change in the agroecosystem. Only a relatively small proportion of the species listed as minor pests are really potential pests in this sense, because of their basic biology.

Secondary or sporadic pest. Defined by Coaker (in Cherret & Sagar, 1977) as a species whose numbers are usually controlled by biotic and abiotic factors which occasionally break down, allowing the pest to exceed its economic injury threshold.

Pest populations. A most important point to remember is that an insect is only an actual pest (in practice) at or above a certain population density, and most control measures are aimed only at reducing this population to a lower level. So insect pest population studies are vitally important, and although mentioned here briefly the topic is included in chapter 2 (page 5), as an aspect of pest ecology.

Pest species accumulation. Long-term stable habitats generally exhibit an extensive species diversity, both in host plants and in phytophagous arthropods. This is shown typically in old forests, and also some plantation crops such as cocoa, rubber, sugarcane and tea (Banerjee, 1981). The pest species accumulation in the monocultures is in part a reflection of the area under cultivation; other important factors are the type of plant, the geographical location of the habitat (area) and its natural species richness, and the age of the actual plants and of the community (crop). It appears that in some cases the age of the plant community is not particularly important, but Banerjee observed that in tea plantations (from the Old World tropics, excluding China) age appeared to be a major factor and pest species saturation was apparently reached (in plantations in N.E. India) at the plantation age of about 35 years. After this age there was no further increase in pest species numbers.

Pest species recruitment. As mentioned elsewhere, each major crop has a more or less clearly defined area of origin in one particular part of the world, and during historical times most of the crops have gradually been transported by travellers and commerce to other parts of the world where suitable climatic conditions prevail.

With some crops, such as *Citrus*, it appears that most of the species in the pest spectrum in most parts of the world are allochthonous in that they have originated in the S. China/Indo-China region where *Citrus* is endemic, and the pests have been gradually spread to the new areas of cultivation. Thus at the present time most of the important *Citrus* pests are pantropical in distribution.

Other crops such as rubber, sugarcane and tea (Banerjee, 1981) have apparently been subjected to autochthonous pest recruitment in their new areas of cultivation. Tea, according to Banerjee, has only about 3% of its total number of pest species common to the different areas of cultivation, the other pests being recruited locally and thus being different in each area.

As would be expected, it appears that with many crops pest recruitment has been in part allochthonous and partly autochthonous. The origin of the crop pest spectrum may have an important effect so far as pest control strategy is concerned, particularly with regard to natural and biological control.

Development of pest status

This takes place through a number of different agencies that fall into two main categories, as follows.

(a) Ecological changes – as already mentioned, these are largely results from the artificial innovations of widespread agriculture.
(b) Economic changes – which are related to the human social context.

An important publication relating to this problem is the 18th Symposium of the British Ecological Society (April 1976) on '*Origins of pest, parasite, disease and weed problems*', edited by J.M. Cherrett & G.R. Sagar (1977).

Ecological changes

There are really only three aspects of importance in considering crop pests, and these are:

(a) state of the pest population (i.e. numbers of pests present);
(b) nature of the damage done to the crop;
(c) value of the damage as assessed by human society.

Thus each aspect of the way in which pests arise through ecological changes will relate to population numbers, for by definition a species is only a pest at or above a particular population density.

Increase in numbers. This is the most common way in which an insect species attains pest status and it usually follows because of one of the factors listed below. But often insect populations can be seen to change, sometimes drastically from a few individuals per plant to literally thousands on the same plant the following season, for no obvious reason at all; probably the most spectacular population fluctuations of this sort are seen with some Diaspididae, Aleyrodidae and Aphidoidea. Presumably there is a subtle population control being effected, but often we are not able to understand it.

Most insects species will have a natural phenological cycle whereby the relatively small number of overwintering (or equivalent) or immigrant adults lay large numbers of eggs and the population develops in a regular, stepped cycle, increasing through each generation of the growing season; finally, there will be a population 'crash' or large-scale emigration at the time of harvest, or the onset of winter (or dry season). The population growth cycle is 'stepped' because of natural predation on the different instars, the earliest instars usually being the most heavily preyed upon. See also the section on pest populations in chapter 2 (page 6).

Population resurgence. The effect of most chemical pesticides is short-lived nowadays, and once the suppressive effect declines the pest population will naturally resurge, possibly up to the economic injury level again.

There may also be resurgence of a secondary pest due to insecticidal destruction of natural enemies, or from some other ecological upset.

Migration. In northern temperate regions a number of pest species regularly migrate into the country in the spring and early summer from farther south where conditions are milder and warmer. In the national pest spectra of the UK, Fennoscandia, Japan, and Canada there are several (or more) quite important migratory species that do not survive the winter locally, but regularly immigrate into the country each year from farther south. This topic is dealt with in more detail in chapter 2 (page 18).

Character of food supply. Plants grown for agricultural purposes have usually been selected for their nutritive value and are typically large and succulent with especially large fruits, leaves and lush foliage. Thus cabbage and lettuce are far more attractive as food for caterpillars than are wild crucifers (such as *Capsella* and *Cardamine*), and *Solanum nigrum* hardly compares with egg-plant, tobacco or tomato as a food source; similarly oats and wheat are far more attractive than wild grasses. A large field containing such a crop represents, literally, an inexhaustible food supply (for at least the duration of the crop) for a potential pest species, so it is little wonder that pests evolved concurrently with the practice of cultivation.

This topic is scarcely distinguishable from the following one in practical terms, especially concerning the use of new varieties and clonal propagation. The growing of new varieties of crop plant can lead to the development of a new

pest species. In Asia new high-yielding varieties of rice were introduced some years ago from IRRI, and in order to achieve the high yields possible the farmers had to use extra nitrogenous fertilizers; the use of these fertilizers produced a lush vegetative growth which seems to be more favourable for BPH reproduction. Thus, as already mentioned, *Nilaparvata lugens* rose in status from a minor pest in the 1960s to its first record as a major pest in 1970, to a generally serious pest in 1975 and a widespread serious pest by 1980. In many parts of Asia it is now regarded as the 'number one' rice pest. This new-found fecundity has also led to a very rapid biotype formation and resistance to many pesticides and resistance-breaking of many new rice varieties.

Monoculture. The growing of a single crop species over a large area provides an unlimited source of food for pest species, especially when the crop plant is particularly succulent. The present worldwide tendency is towards mechanized agriculture which requires larger fields and fewer hedgerows which traditionally delimited each field, and so the crop monoculture becomes even more extensive. This practice will encourage some insect species to become more abundant, and hence important as pests, as was observed about a century ago with Colorado Beetle on potatoes in the USA (see fig. 8).

As well as monoculture becoming more extensive, some new crop varieties have become more specialized in their growing conditions, and there is a tendency to reduce the extent of crop rotation.

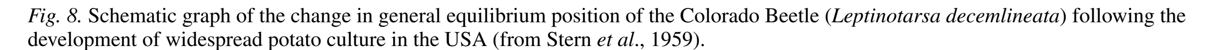
As mentioned before, the taiga of northern Asia and America with its coniferous forest dominated by only a few tree species, and the northern temperate oak/beech forests, are the natural equivalents of an agricultural monoculture. Thus it is not surprising to learn that *Quercus* is attacked by 1000 different species of insects!

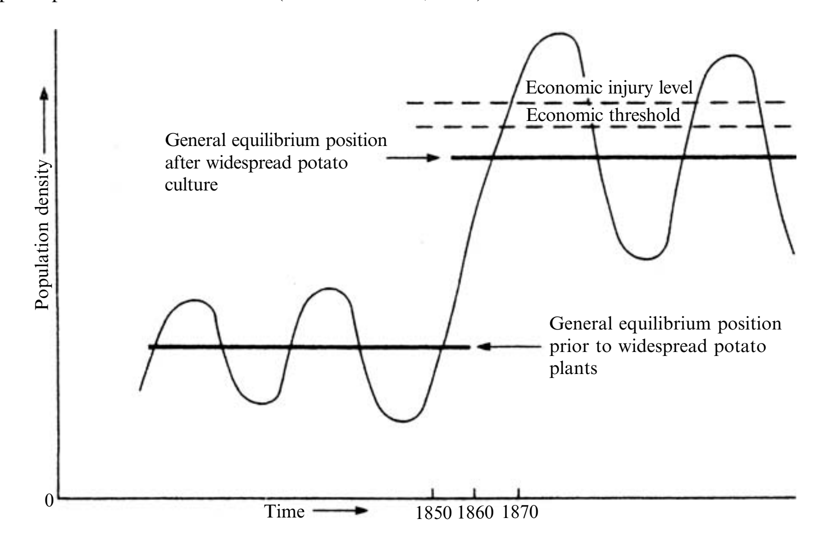
The extensive increase in rape as a commercial crop in many parts of Europe has resulted in a number of pests that attack the flowers and pods becoming far more abundant and widespread, and thus putting *Brassica* seed crops more 'at risk' than formerly.

Farmers also often specialize in particular crops for reasons of convenience, both agriculturally and economically, so that, for example, in parts of eastern England and eastern Canada where the fenland peats (and mucklands) occur, it is common practice to grow carrots, rotated with celery and parsnip, because they all require similar soil conditions, but from a pest point of view this is scarcely a rotation as all belong to the Umbelliferae and have a similar pest spectrum. The more extensive a monoculture becomes then the greater is the pest problem, generally.

Certain regions of Canada, the USA and the USSR are referred to as the 'wheat belts', and here the annual wheat crops are measured in square kilometres or square miles, rather than hectares. This practice has evolved in part because of the national need for cereals, but also because the climatic and edaphic factors prevailing limit crop production to plants that require little water.

A recent trend in agriculture is towards extreme standardization of product, for a number of different reasons connected with both crop production and product utilization. A good example is rubber in Malaysia. After World War II it was thought that synthetic rubbers (produced from oil) had destroyed the natural rubber (NR) market. However, it was found that natural rubber possesses qualities that have not been matched by synthetic rubber. Then in 1965 new cultivation


Fig. 8. Schematic graph of the change in general equilibrium position of the Colorado Beetle (*Leptinotarsa decemlineata*) following the development of widespread potato culture in the USA (from Stern *et al.*, 1959).



methods and processing produced the new Standard Malaysia Rubber (SMR), constant in quality to tight specifications. There is now a tremendous world market for natural rubber, and this industry is booming throughout S.E. Asia, mostly through new improved methods of production.

These new production methods include *cloning*, the vegetative mass-production of ideal genetic stock through mist-propagation and other techniques. Clonal propagation of oil palm in Malaysia and S.E. Asia is proceeding rapidly at present as this industry expands throughout the region. To have large areas of genetically identical trees is very useful from both crop production and product-processing points of view, but these trees are vulnerable to disease and pest epidemics by virtue of their uniformity, and the most serious threat would be from a new major pest or disease which might arise. Clonal cultivation clearly represents the most extreme form of monoculture.

Oddly enough, in the very large-scale monocultures, such as the wheat fields on the Canadian prairies, there is the rather anomalous situation whereby the wheat monoculture is regarded as a highly stable habitat with a diminished pest problem. On reflection this situation is not so strange because the extent of the wheat monoculture is very great. It seems that each extreme of habitat diversity (from tropical rain forest to prairie wheat) is stable with a reduced pest problem, whereas it is the intermediate stages in the process of simplification that suffer the greatest pest problems.

Mixed stands (*mixed cropping*) are being recognized as a cultural method of alleviating pest situations (Way, in Cherret & Sagar, 1977), and it is being developed successfully for use in barrios in the Philippines by IRRI. For large-scale agriculture, with the present reliance on mechanization, mixed cropping is generally not feasible, but for small peasant farmers in the tropics and for smallholders it can be a valuable means of combating pest infestations. In the tropics by far the greatest area of crops is actually grown on smallholdings and not the huge agricultural estates characteristic of the northern temperate regions.

Continuous cropping. The plantation and orchard crops are all very long-term and because of this they suffer from particular pest problems, but in compensation their pests are to some extent controlled by natural enemies. Field crops are typically characterized by their short duration (an ephemeral habitat) as at most they are annuals, and sometimes by careful timing the crop may be grown before the pest population catches up. However, there is pressure of late to produce a continuous supply of vegetables, and new varieties tolerant of different climates have been bred. In the vicinity of large urban conurbations many vegetables are now being grown almost all year round. For example in S. China and S.E. Asia, by varying the varieties grown, it is possible to produce onions, tomatoes, and several species of *Brassica* continuously for the local markets. This encourages the build-up of the pest populations; for instance throughout Asia, Diamond-back Moth and Turnip Mosaic Virus have now both become serious pests of *Brassica* crops.

Minimum cultivation techniques. A recent agricultural technique in ground preparation is known as minimum cultivation, and it consists essentially of a chemical destruction of old crop remains and weeds, followed by a subsequent planting of the new crop into the undisturbed soil. Ploughing and harrowing normally reduce the population of soil pests by exposing them to sunlight and desiccation, and to predators and parasites. Many Coleoptera, Lepidoptera and Diptera feed on the aerial parts of plants as larvae but pupate in the soil. These and other soil-inhabiting pests would normally be depleted in numbers by normal cultivation methods, and so in areas where minimum cultivation techniques are employed there is often a build-up in numbers of soil pests.

Multiplication of suitable habitats. Farming leads to a simplification of the flora by a selection of plants suitable for husbandry. Thus insects associated with these plants have a more attractive and concentrated food supply, as well as a greater total host number. The most outstanding example of this is shown in the storage of grain and foodstuffs; many storage pests exist in small populations in the field but increase enormously in numbers in the favourable micro-climate and abundant food of the grain store. Examples are to be seen in *Sitophilus* on maize cobs, *Sitotroga* on sorghum, and the Bean and Cowpea Bruchids.

Loss of competing species. Under conditions of monoculture an area harbours fewer insect species than under ‘natural conditions’, and many insects now become pests which were not pests under the natural conditions. Sometimes specific pest control measures may remove one pest, but another insect released from competitive pressure may increase in numbers and become a new pest. Once the new pest is established mutations make the relationship between it and the crop even closer, for as numbers increase more mutants appear and can be selected to consolidate their niche as pests.

Change of host/parasite relationships. Many insects are kept in check by their predators and parasites, although when a pest species increases in number there is typically a time-lag between its increase and the parasite and predator numbers. Parasites are generally quite specific but predators less so, and the time-lag of the parasite population build-up is generally less than that for a predator. The greater the time-lag between the pest population increase and that of the parasite or predator, then the more likely is the species to be a serious pest. Generally agricultural operations involving large-scale insecticide applications may affect parasites and predators more than the pests. One of the classical cases is that of the Fruit Tree Red Spider Mite (*Panonychus ulmi*) which became a more serious pest on fruit trees after widespread use of DDT in orchards throughout Europe and North America.

Spread of insects and crops by man. Almost every major crop was once endemic only to one particular part of the world, but during the centuries of world exploration and trade most crops were distributed throughout the regions which had a suitable climate for their cultivation. This state of affairs is generally highly desirable, especially since some crops flourish in their new habitats (e.g. rubber in Malaysia, coffee in S. America and potatoes in Europe) and most countries now aim at agricultural diversification. Unfortunately some of the endemic crop pests were accidentally (or otherwise) distributed along with the crops (or afterwards) and became serious pests in the new locations, for they were usually without the restraint of their endemic natural enemies. Several aspects of this problem are reviewed in the book by Elton (1958). The main means of pest dispersal by human agency are as follows.

Dispersal by unknown means. Some pests (and crops) appear to have been dispersed since antiquity, though it is not clear how this dispersal was effected. It must be remembered that in some parts of the world there have been human population movements ever since the early days of agriculture. Also, of course, all animal species have an innate tendency to disperse, or migrate, of their own accord. However, there are numerous records of crop pests having been spread by man, either accidentally or intentionally.

Transport on the host (plant). The symbionts that normally live with man and his animals have been transported to all parts of the world, and likewise the transport of live plants provides an easy mechanism for the dispersal of many pests, especially scale insects, mealybugs, and aphids on the plants, and beetles, nematodes, moth pupae, etc. in the soil around the roots. It is only recently that phytosanitation measures have been adopted. Classical cases include the spread of *Icerya purchasi* around the Mediterranean on nursery stock, and also several scale insects on *Citrus* and other fruit stocks from S. China to California, Hawaii and Australia. Hessian Fly (*Mayetiola destructor*) is thought to have been transported to N. America from Europe in wheat straw. Colorado Beetle was brought from the USA to Europe (France) on stored potatoes.

Dispersal through trade. Rats, many weeds, and some insects have been dispersed over the international trade routes, usually accidentally, in either produce (as above), containers or ballast. A recent case of note is the spread of Rice Water Weevil from the USA into Japan, where unfortunately it is now established. It is thought that weevil pupae were present in hay exported to Japan for use by dairy farmers, and they were then carried into rice fields in the manure from dairy farms. About half the immigration records for Colorado Beetle in the UK are from produce (seldom potatoes) in ships arriving at coastal ports in southern and eastern England.

Stowaways in air transport. With the recent development of international airways and rapid transport from one part of the world to another, there is a constant danger of insect pests being transported live from one region to another. This threat applies also to medical pests (especially vectors) which is why aeroplane cabins are sprayed with aerosol insecticides prior to passenger departures. Several of the records of Colorado Beetle introductions into the UK are clearly cases where the beetles were stowaways in the undercarriage of the planes from Spain and France, and the beetles were dropped along the airport approach line as the undercarriage was lowered.

Deliberate introduction by man. The most notorious examples are without doubt the introduction of prickly pear cactus (*Opuntia* spp.) and rabbit into Australia. Many other examples are listed by Simmonds & Great-head (in Cherrett & Sagar, 1977) and include the Gypsy Moth (*Lymantria dispar*) imported into the USA in about 1870 by an amateur entomologist to test its value for silk production. Some moths escaped and became established as one of the most serious forest pests in the north-eastern USA.

Economic changes

The definition of a pest relates clearly to the value of the damage done by the insect (or animal) as assessed by human society, and so any changes in the value of the crop will affect the importance of the pest. Damage that is not important when prices are low can be very serious when prices are high. Sometimes the converse situation is true, if an important food crop is in short supply then some pest damage may be tolerated.

Change in demand. If some crops are replaced by others, the pests of the former crops become less important. Greater demand for a crop increases its value and the incentive to grow it. The demand may be for increased quantity and quality, both of these factors affecting the importance of the pests. If the crop is in short supply the consumers are less selective than if it is abundant. Wireworms do not greatly affect the yield of potatoes, but their tunnels spoil the appearance and keeping qualities. If the supply is short, consumers overlook a little damage, but with the recent demand for packaged vegetables such potatoes are generally unsaleable, thus making wireworms a much more serious pest.

Change in production costs. A pest may become economically important when agricultural practices change. If a new high-yielding variety is developed, minor pests which attack it may become of economic importance.

The case of the Brown Planthopper becoming a serious pest on new rice varieties is complicated in that, in order to achieve the high yield possible from these new varieties, it is necessary to use more fertilizer on the crop. The extra fertilizer produces a lush foliage which induces the BPH to a higher level of fecundity, making it a serious pest on a now more expensive crop.

Crops for export are more valuable than those for local consumption. In Europe it is now possible to buy fresh peppers,

aubergines, avocados, and many other tropical fruits and vegetables that are being air-freighted from Africa, the Middle East and other tropical regions. These crops are of course now much more expensive to produce (and sell) because of air freight but are sold at correspondingly higher prices.

Pest damage

This is considered in more detail later (chapter 5) but is mentioned here briefly because of its implications in connection with choosing a pest control strategy. The single most important aspect is the relation between the damage done by the pest and the part of the plant harvested. *Direct damage* is when the part of the plant to be harvested is the part attacked, such as the leaves of tobacco, fruits of tomato and apple, tubers of potato and sweet potato; in these cases clearly the damage is more important. *Indirect damage* is when the part of the plant damaged is not the part to be harvested. Examples include the roots of tobacco and wheat, leaves of sugarbeet, potato and apple. In these cases it is usually possible to ignore quite surprisingly high levels of pest infestation, as these infestations may only have a marginal effect on the crop yield.

Direct effects of insect feeding

Biting insects may damage plants as follows.

(a) Reduce the amount of leaf assimilative tissue and hinder plant growth; examples are leaf-eaters, such as adults and nymphs of locusts and *Epilachna* and larvae of *Plutella*, *Pieris*, *Plusia* (Lepidoptera) and sawfly larvae.
(b) Tunnel in the stem and interrupt sap flow, often destroying the apical part of the plant; these are stem borers and shoot flies, such as *Zeuzera* in apple branches, *Cephus* in wheat, *Ostrinia* in maize, *Atherigona* in maize and sorghum.
(c) Ring-bark stems, for example some Cerambycidae.
(d) Destroy buds or growing points and cause subsequent distortion or proliferation, as with Fruit Bud Weevils (*Anthonomus* spp.) on shoots of apple, pear, etc.
(e) Cause premature fruit-fall, as with Cherry Fruit Fly, Codling Moth, Apple Sawfly.
(f) Attack flowers and reduce seed production, as with the blossom beetles (*Meligethes* spp.) and Japanese Beetle.
(g) Injure or destroy seeds completely, or reduce germination due to loss of food reserves; examples are Hazelnut Weevil, Maize Weevil, Pea and Bean Bruchids, Pea Pod Borers, and Bean Pod Borers.
(h) Attack roots and cause loss of water and nutrient absorbing tissue, as with wireworms and various chafer larvae (Scarabaeidae) and other beetle larvae in the soil.
(i) Remove stored food from tubers and corms, and affect next season's growth; examples are cutworms and wireworms in potato, and Potato Tuber Moth larvae.

Insects with piercing and sucking mouthparts may damage plants as follows.

(a) Cause loss of plant vigour due to removal of excessive quantities of sap, in extreme cases wilting and foliage distortion results, as in the stunting of cotton by *Bemisia* (Whitefly), and aphids on many plants.
(b) Damage floral organs and reduce seed production, for example capsid bugs (Miridae) and other Heteroptera (Wheat Shield Bugs, Chinch Bugs, etc.).
(c) Cause premature leaf-fall, as do many diaspidid scales.
(d) Inject toxins into the plant body, causing distortion, proliferation (galls) or necrosis; examples are seen in capsid damage on bean leaves and shoots, and the stem necrosis on plants by *Helopeltis* and other Heteroptera.
(e) Provide entry points for pathogenic fungi and bacteria, as does *Dysdercus* on cotton bolls (for fungus *Haemospora*) and other bugs.

Indirect effects of insects on crops

(a) Insects may make the crop more difficult to cultivate or harvest; they may distort the plant and cause the plant to develop a spreading habit which makes weeding and spraying more difficult. They may delay crop maturity, as do the bollworms on cotton, and grain in cereals may become distorted or dwarfed.
(b) Insect infestation results in contamination and loss of quality in the crop; the quality loss may be due to reduction in nutritional value or marketability (lowering of grade). Loss of yield in a crop is obvious but a nutritional quality loss is easily overlooked; this is the type of damage done to stored grain by *Ephestia cautella* and *Tribolium*. A more common loss of quality is the effect of insects on the appearance of the crop, for example skeletonized or discoloured cabbages have a lower market value than intact ones. Attacked fruit is particularly susceptible to this loss in quality, as seen by skin blemishes and hard scales on citrus fruit and capsid damage on apples. Contamination by insect faeces, exuviae, and corpses all reduce the marketability of a crop, as do black and sooty moulds growing on the honeydew excreted by various homopterous bugs. A major problem in the tropics is 'stickiness' of cotton lint caused by honeydew from Cotton Whitefly; the sticky cotton is difficult to gin, and its value is diminished.
(c) *Transmission of disease organisms*
    (1) Mechanical transmission, also termed passive transmission, takes place through feeding lesions in the cuticle. Sometimes the pathogen (usually fungi or bacteria) is carried on the proboscis of the bug or sometimes it is on the body of the tunnelling insects. Examples are seen in the case of the *Scolytus* beetles which transmit Dutch Elm and other fungal diseases.

(2) Biological transmission. Most viruses depend upon the activity of an insect vector for transmission. The vector is usually also an intermediate host, as is the case with most aphid and whitefly hosts. Diseases transmitted in this manner include Cucumber Mosaic, Tobacco Mosaic and Turnip Mosaic.

Economics of pest attack and control

Economics in this sense is the relation of crop losses to production costs. Sometimes due to pest outbreaks a particular crop may be scarce and sell for a higher price, so that the individual producer may not suffer financially. From the economic point of view, however, one must consider the overall (national) picture, not just individual producers.

Decision to take action

This decision is based upon an accurate estimation of the cost of control measures in relation to possible profits likely to accrue as a result of control. The *economic threshold* in pest control is the point at which a particular pest can be controlled at a cost of less than the expected market value of the expected yield increase. Often the cost of control may be known very accurately but the possible profit is a subjective assessment based upon past experience and guesswork. Because many pest control costs are relatively low, against a serious pest attack it is usual for no calculations to be made; none are needed! However, sometimes costs are critical, for some pesticides are quite expensive and their use at the recommended rates may be prohibitive in cost to the small farmers and generally can only be afforded by the large estates. Impressions of the degree of infestation of a crop are often wrong or else very misleading; temperate examples include the infestation of Mangold Fly on sugarbeet, where the damage is often striking and unsightly, but experiments have shown that 70% defoliation reduces the yield by only 5%, and a 50% defoliation has no measurable yield loss. Similarly Black Bean Aphid infestation on spring-sown field bean stems is misleading in that an early infestation which looks only light can reduce the yield by as much as 30%; in this case damage is more serious than would appear at first sight.

In some areas certain crops are always *at high risk* from particular pests, as shown by years of empirical observations, and in these cases preventative pesticide applications are usually made, often in the form of granule application at the time of sowing or else seed dressings.

There is a definite danger though that in some areas the mere sight of a particular key pest in a crop will precipitate panic action by a farmer who will immediately spray with insecticides when in fact their application might not be necessary.

Cost/potential benefit ratio in decision

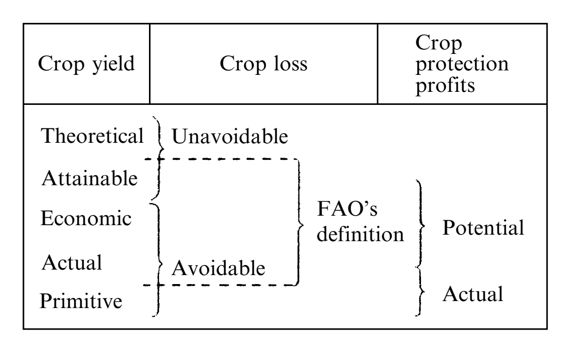
In practice, cost/potential benefit ratios are only known for valuable crops like citrus and apples, and usually then apply only to the benefit likely to result from control of the heaviest infestations that may occur. Generally little account is taken of differences in infestation and prices; thus spray programmes planned using this concept are only applicable to comparatively steady rates of infestation and cash return. When the ratio is high, uncertainty about the likelihood of attack can be ignored. Seed dressings are a cheap form of protection and can give a cost/potential benefit ratio as high as 1 : 10, when used against severe attacks of Wheat Bulb Fly or wireworms. Doubt as to whether they are needed on each occasion wheat is planted after fallow (danger from Wheat Bulb Fly) or ploughed-up pasture (wireworm) is usually discounted because the ratio of 1 : 10 need only be reached once in ten times for the operation to break even with regard to costs. Surveys for use of insecticides against wireworms on potato lands in the British Isles by the National Agricultural Advisory Service (now ADAS) have shown that in only 25% of fields is there likelihood of wireworm damage. Therefore the cost/potential benefit ratio must be at least 1 : 4 for treatment to be profitable on average, but attacks are seldom severe enough to give a ratio of 1 : 10, and so an average of 1 : 4 or more for treated fields is unlikely. Thus treatment of all potato fields is not only unnecessary three times out of four, but the total effect is to increase the cost of production of potatoes and probably to decrease growers' profits. Surveys have shown that after the decline of wireworms as serious pests some years ago, many farmers continued to apply soil insecticides in the UK (despite the low levels of damage recorded) which was quite unnecessary. Experience has shown that often growers continue a treatment long after the need for it has finished.

Relation between yield increase and pesticide dosage

If a graph is drawn showing the relationship between rate of application of pesticide and percentage increase in crop yield, it is apparent that the curve is sigmoid but slightly asymmetrical. At the lower application rates the yield increases are low; at higher application rates the increase becomes high and then gradually decreases; finally, the yield increase decreases rapidly. It is possible to calculate a dosage response curve for a particular pest at different population densities, which shows what control measures are necessary, and also shows the rate of application at which profits no longer increase. However, if the dosage response curve is to be used to decide upon the correct pesticide use, the relationship between yield and infestation must be known, and the populations likely to cause economic damage must be predicted. Unfortunately, this relationship and prediction cannot yet be made very accurately for most insect pests.

Crop yields. When referring to crop yield in relation to pest infestation and damage levels, it should be borne in mind that in practice there are various levels of crop yield, as shown in fig. 9 (CAB/FAO, 1971). *Primitive* yield is the lowest, and

Fig. 9. Interrelation between crop yield, crop loss and crop protection profits.



refers to the situation where none of the modern agricultural inputs (improved seeds, mechanized tillage, irrigation, fertilizers, and crop protection) are used. *Actual* yield is the crop yield actually attained through partial use of these inputs. *Attainable* yield is what could be achieved under optimal conditions with maximum input. *Economic* yield is that which gives the highest return financially on investment, and is usually lower than the attainable yield. *Theoretical* yield is the highest, and it represents the upper limit of crop production calculated by crop physiologists.

Economics of national pest control programmes

Most of the cost of pest control programmes is borne by the consumer in the price which he pays for food. However, the cost of quarantine, eradication of imported pests, biological control, and much of the cost of research into pest biology is met through government expenditure. The cost of the UK quarantine laws against Colorado Beetle is probably in the order of £50 000 per year, or 4 p per hectare to be added to the cost of the potato crop; this is a very good investment when compared with the losses which a heavy attack would cause. Attempts to eradicate a newly established pest by chemical control can be very costly. After the Mediterranean Fruit Fly was accidentally introduced into Florida a total of 2 million hectares of citrus land and adjoining land was sprayed at a total cost of some £3–4 million, yet the entire operation cost no more than about 5% of the annual value of the citrus crop and saved the industry.

The cost of biological control programmes is sometimes difficult to estimate, but DeBach (1964) said that for the Department of Biological Control of the University of California for the period 1923–59, a total expenditure of £10½ million has resulted in a saving on five projects of £40 million, with a recurrent benefit of £10½ million. Thus it can be seen that the cost of biological control does compare very favourably with chemical control.

Pest assessment

In sampling and assessment programmes it is found that the relationship between pest numbers and damage is often logarithmic rather than linear, and it is usually more effective to take many samples and separate them quickly into different, easily distinguished, categories of infestation, than to carefully count numbers of pests on a few samples, if the results are to be statistically analysable.

It is highly advisable to seek advice from a biological statistician, when planning a sampling and assessment programme, in order to ensure that the results obtained will be suitable for statistical treatment. The publication by FAO/CAB (1971) includes details of damage assessment for about 80 major pests of 27 crops (see chapter 5 for more detail). In the UK pest assessment details for some crops are available from local ADAS offices.

Efficiency of pest control measures

Methods of pest control tend to operate with a characteristic *efficiency* in that they reduce pest populations by a fixed proportion, more or less regardless of the number of pests involved. The efficiency of a treatment can be expressed as the percentage reduction of the pest population, or of the damage. It therefore follows that the numbers of a pest surviving a treatment depend upon the numbers attacking the crop, as well as the efficiency of the control measure. The efficiency of an insecticide treatment invariably declines with time since application, and is closely related to residue persistence, the growth of the crop, type of soil, sunshine, and moisture level.

The *effectiveness* of a control measure, as distinct from its efficiency, is reflected by the number of pests surviving after treatment, or, from a practical point of view, the amount of damage occurring after treatment. Thus a control measure will be most effective when dealing with relatively light infestations. Consequently, any actions which reduce a pest population will automatically improve the effectiveness of a control treatment, even though the efficiency of that treatment remains unchanged. Conversely, any practice encouraging a high population density in an area will immediately reduce the effectiveness of the control treatment, often giving the false impression that the treatment no longer works. The kinds of action which encourage a pest population buildup are destruction of predators and parasites, insufficient crop rotation, presence of weeds and alternative hosts in the vicinity of the crop, a low standard of crop hygiene, etc.

Forecasting pest attack

The ultimate goal of pest control programmes is the accurate forecasting of pest attacks before they actually take place, so that control measures can be planned with maximum efficiency. Successful forecasting techniques should be as simple as possible, and will be based upon detailed knowledge of the biology and ecology of the pests concerned. The types of detailed studies required to give the basic information are as follows.

Quantitative seasonal studies which must be made over several years to determine seasonal range, variability

in numbers, and geographical distribution. Such studies must use sampling methods appropriate to the pest and its abundance, and the seasonal counts should be related to climate and topographical data.

Life history studies, to find the length of the life cycle, number of eggs laid, amount of food eaten, maturation period for the females, are aspects that can be studied both in the field and in the laboratory. Behaviour of different larval instars and possible number of generations under different conditions can most suitably be studied in the laboratory. The expected range in relative humidity, temperature, etc., can be considered in relation to limits of survival of the insect under study.

Field studies to find the effects of weather on the pest. Either directly or indirectly climatic factors control pest numbers, affecting not only the pests themselves but also their predators and parasites. The ways in which pests spread from crop to crop are largely influenced by weather. Until population dynamics of insects are more fully understood, accurate forecasting is very difficult, and generally the many forecasting schemes in different countries have met with widely differing successes. The National Agricultural Advisory Service (now ADAS) in Great Britain is usually quite good at making pest outbreak forecasts. The essential point of forecasting is to predict the timing of critical pest populations, or populations reaching the economic threshold. In this section the term forecasting is used in the wide sense to include simple spray warnings based upon first occurrence records, as well as more complicated forecasting by prediction.

Emergence or occurrence warnings
(pest monitoring)

In temperate regions these are basically emergence warnings as the first of the overwintering eggs hatch, or the first adults emerge from the overwintering pupae. Because of the climatic regulation most emergences take place over a relatively short period of time and are not too difficult to monitor. In the tropical parts of the World, where weather conditions permit continuous breeding of the pests most of the time, the warning is basically for the first occurrence of the pest in the crop, or sometimes the recording of immigrants from an adjoining area. In southern Japan on the island of Kyushu there are several serious rice pests which are unable to overwinter and which arrive from E. China each summer as aerial immigrants. In the areas at risk from these pests large wind-traps are mounted along the coast to sample the anemoplankton (small insects carried on the wind or air currents) to detect the arrival of these visitors. In these different cases, this type of warning is applicable only where the pest is known to be a serious one, and when economic damage is to be expected, based upon years of previous empirical experience. Such a crop is referred to as being at *high risk*.

In its simplest form, this type of warning consists of a visual record of adult insects in the vicinity of the crop, otherwise the use of different types of traps is required. To make this method more reliable it is preferable to use a trap that actively attracts the insects and so will be effective at lower pest densities; if electricity is available in the field then an ultra-violet (u.v.) mercury-vapour light-trap (sometimes called 'black-light') can be used for some species such as moths and leafhoppers. Black-light traps are used to monitor the arrival of migratory rice leaf-hoppers in Japan, and are used to such an extent throughout China for pest monitoring that electricity cables run throughout all the agricultural areas of eastern China. In some cases the u.v. traps are of a sufficient density to be also used for the '*trapping-out*' of several pest species. Otherwise pheromone traps are very good, and quite a few pheromones are now commercially available in most countries. Codling Moth warnings are based upon both pheromone and u.v. light trap catches; fruit flies of the genus *Dacus* are easily trapped using 'Cu-lure' or methyl eugenol baited traps. Warnings of danger from locusts and armyworms usually rely on sight records of hopper or adult swarms. Suction traps are suitable for small flying insects such as aphids and midges, but the more active fliers can elude the trap easily. Sticky traps are cheap to make and easy to handle, and by adjusting the level of stickiness it is possible to catch only the correct sized insects. But the efficiency of such traps is rather dubious and may require some trial runs to establish whether it is a suitable method for any particular pest. For some small insects water traps can be quite effective. Some traps such as sticky and water traps may be more effective if coloured yellow, as it seems that a number of pests find the colour yellow attractive.

Emergence traps fixed on the soil between the crop plants are very suitable for species that pupate in the soil or litter, such as some Diptera, Lepidoptera and Thysanoptera, but care has to be taken for such traps may heat the soil and cause precocious emergence.

The use of traps as an ecological tool for the assessment of population size is highly problematical, and requires great care and forethought, but for forecasting use most of the time all that is required is a record of the first emergence or occurrence in the crop. In some temperate situations empirical studies over many years can link certain levels of trap catches (e.g. Codling Moth) with particular levels of infestation and crop damage. For details concerning methods of trapping see Southwood (1978) and in McNutt (1976) various types of traps are illustrated.

Spray warnings based on such trapping methods have to make due allowance for the female maturation period, rate of oviposition and time required for egg development.

Forecasting by sampling

Strictly speaking there is no real difference between this category of forecasting and the previous one, for in both cases the pest population is being sampled (and monitored), but for practical purposes there is some merit in treating them as distinct. The study of the development of a pest population is now often referred to as *pest monitoring*.

By sampling immature stages of insect pests it is possible to arrive at approximate estimations of numbers expected in later stages. The further back in the life history one samples, the less reliable will be the method, because of the difficulty in estimating natural mortality rates. Thus, it is rather unreliable to sample fly pupae in the soil in the autumn (for example in the UK); it is more useful to sample eggs in the soil (around the plants) in the following spring. In the UK the taking of soil cores for insect eggs of Carrot Fly and Cabbage Root Fly is quite successful for estimating later population of root maggots, and hence determining whether or not to apply insecticides.

With pests that have alternative hosts, they may be sampled while on the other host, so that an estimate of their probable pest density on the crop can be made; this method has most application in temperate regions where the pest overwinters as eggs on another plant, e.g. Peach–potato Aphid; Black Bean Aphid is often sampled as overwintering eggs on spindle trees.

With many Lepidoptera it may be feasible to determine the best spraying date by the finding of eggs on the crop. This is done with various pulse moths (Pea Moth, etc.), some stem borers and many of the bollworms of cotton. In many parts of Africa the major cotton bollworms are *Diparopsis* and *Heliothis* and crops at risk are examined either in the field or else samples taken back to the laboratory to search for eggs and/or young larvae.

Forecasting by prediction

Temperature. Temperature is the single most important factor controlling insect development and hence population numbers. A simple method using mean temperatures for two months has been developed to predict the date of emergence of the adult of the Rice Stem Borer (*Chilo simplex*) in Japan. It has also been used in the USA for the prediction of outbreaks of the European Corn Borer (*Ostrinia nubilalis*). A base temperature of 10°C is used, and the amount of development the pest attains daily is indicated by the number of degrees above 10°C each daily mean temperature reaches. The accumulation of these departures from the base temperatures in one season is expressed as *degree-days*. Observations over several years have given the number of degree-days required and have equated these with each stage of development.

Rice Leaf-roller has recently become a serious pest of rice in Japan, and here it is recorded that there are five larval instars on young plants and six instars on the ripening crop, usually with three generations each season in Japan. The second generation requires 210 degree-days for development, whereas the later, third generation requires 300 degree-days.

The developmental requirements, in terms of degree-days, are now known for a large number of pests in several different countries, mostly in Canada, USA, Japan and Europe (including the UK). Information on this matter may be obtained from the appropriate national research station in most countries.

Rainfall. Rainfall has also been used to forecast the likelihood of pest attack. In Tanzania outbreaks of the Red Locust (*Nomadacris septemfasciata*) have been forecast from an index of the previous year's rainfall, and in the Sudan the amount of pre-sowing rains frequently enables jassid damage to the cotton crops to be predicted.

Generally rainfall-based predictions are tenuous at best, and this line of research does not appear at present to be very profitable.

Climate. A climatograph (see fig. 4) will show the relationship between the basic pest requirements and the prevailing conditions in the area in question. This will give an indication as to the likelihood of the pest becoming established in that area. Such studies have formed the basis for many of the international phytosanitary regulations, when it has been shown that there are areas where a particular pest could become established because the climatic conditions are suitable and if introductions were permitted.

The final type of prediction is based upon observation of climatic areas, for on this basis some areas where critical infestations are likely to occur can be predicted for some pests. The principal factors controlling a pest population build-up may be climatic, biotic and topographical, although a combination of temperature and relative humidity (or rainfall) is probably the most important.

Knowing the temperature and relative humidity requirements for the different instars of an insect species and knowing the climatic conditions of an area, enables the likelihood of an outbreak of that pest in the area to be estimated.

The effects of climate upon insect pests is discussed in more detail in chapter 2 (page 16).

4 *Methods of pest control*

There is a large number of different methods of pest (including disease) control available to the crop protectionist, but careful deliberation is required in making a choice of methods. In general the orientation of the control project is towards the crop plant population rather than individual plants, so that low levels of pest infestation are acceptable provided that damage levels are low. Obviously with some expensive horticultural crops the welfare of each individual plant is of concern.

The choice of method(s) to be used depends on several factors.

(a) Degree of risk – some crops in some fields are at *high risk*, because in that area serious pests are invariably present in large populations. In such situations *preventative* measures (sometimes called insurance measures) may be justified. Similarly a high risk area may be predicted by sampling and forecasting techniques.
(b) Nature of pest and disease complex – usually several (or many) different pests and pathogens will be interacting on the crop in the form of a pest complex. Key pests will dominate the control strategy. With many crops between four and eight major pests will require control at any one time. Ideally the method(s) used will control several pests (and sometimes pathogens also) simultaneously.
(c) Nature of the crop and agricultural system – e.g. height of crop and spacing.
(d) Economic factors – e.g. cost of chemicals and specialized equipment.
(e) Ecological factors – e.g. extent and type of natural control, and availability of water.

Obviously it is vitally important that the pests be correctly identified and that their general biology be known.

The system of classifying control measures which follows is based upon the mode of action, and is widely used by plant pathologists.

(a) Exclusion – including quarantine, use of disease-free seed and planting material; designed to keep (new) pests and diseases out of an area or crop.
(b) Avoidance – uses cultural control methods and sites free of infection, and resistant crops.
(c) Protection – use of chemicals mostly, as protectants, therapeutants and disinfectants; physical protection may be included; anticipated protective measures are termed preventative.
(d) Eradication – for an outbreak of a pest or disease in a new area; uses soil sterilization, fumigation, heat treatment, insecticidal saturation, etc.

Generally it is more useful, from a pest viewpoint, to regard control measures according to their basic nature, as follows:

(a) legislative methods
(b) physical methods
(c) cultural control
(d) crop plant resistance to pest attack
(e) biological control
(f) chemical control
(g) integrated control
(h) integrated pest management (pest management)
(i) eradication

Legislative methods

These are obviously methods of control where government legislation (laws) has been passed so that certain control measures are mandatory, with failure to comply being a legal offence. These are extreme measures and only apply to certain very serious pest situations of national importance.

Phytosanitation (quarantine)

When the major crops were distributed around the world from their indigenous areas, initially they may have been free of their native pests and diseases (particularly crops grown from seed). But over the years many reintroductions have been made and gradually the native pests and pathogens have spread also, until now when some pests and diseases are completely sympatric with their host crops. However, there is still a large number of pests and diseases that have not yet spread to all parts of the crops' areas of cultivation. For example, the early success of coffee in Brazil (S. America) was due to the absence of Coffee Rust, Antestia Bugs, and Coffee Berry Borer, which remained behind in E. Africa; but this advantage has now been lost as in recent years both Rust and Berry Borer have become established in S. America. Similarly the success of rubber as a crop in S.E. Asia is due in part to the absence of its native South American Leaf Blight.

FAO (Food and Agriculture Organization of the United Nations) have organized a system of international plant protection with respect to the import and export of plant material. The world is divided into a number of different geographical zones for the basis of phytosanitation; each zone has its own regional organization for coordination. There is now an International Phytosanitary Certificate, an essential document required for importation of plant material into almost every country of the world.

Disease-free and pest-free plants can usually be imported, provided they are accompanied by appropriate documentation from the country of export, but certain plants (and fruits) are completely prohibited because of the extreme likelihood of their carrying specific noxious pests or pathogens. Other categories of plants are allowed to be imported (and exported) after routine treatment to eradicate possible pests; such treatment usually consists of fumigation (e.g. fumigation of fruit in the USA using ethylene dibromide). Sometimes the plants have to be kept in quarantine isolation for a period of time to check that no symptoms develop (as with domestic pets and rabies quarantine). Specific import regulations vary from country to country according to the nature of the main agricultural crops; thus California and Florida are very concerned about *Citrus* fruit import, and Hawaii has rigorous regulations concerning orchids. Importation of pome fruit into many countries from Asia and America is very rigorously controlled because of the danger of importation of San José Scale (*Quadraspidiotus perniciosus*); this is potentially the most destructive orchard pest and caused tremendous damage to commercial orchards in the southern USA at the turn of the century, attacking all types of pome fruit, plums and cherries, in addition to shade trees and ornamentals. The terminal stages of infestation usually resulted in the death of the trees. California Red Scale (*Aonidiella aurantii*) is a serious pest of *Citrus* that is not yet quite pantropical, so that citrus fruit importation is subjected to careful scrutiny in several tropical countries.

For further information on international phytosanitation see Caresche *et al*. (1969) and Hill & Waller (1982).

Prevention of spread

A very serious temperate pest is Colorado Beetle (*Leptinotarsa decemlineata*), first observed in the semi-desert areas of western USA in 1824, feeding on the foliage of a wild *Solanum* species. When the cultivated potato was introduced into this area the beetle found a new and more desirable source of food, and in a short period of time both potato cultivation became widespread in the USA and the Colorado Beetle spread rapidly. By 1874 it had reached the Atlantic seaboard of the USA and both Ontario and Quebec in Canada. The first record of Colorado Beetle in Europe was in Germany in 1876, and in 1877 a single beetle was found in the Liverpool docks. In the UK it was realized that this was potentially a very serious pest and that measures were required to prevent its establishment in Britain; in 1877 the Destructive Insects Act was established, the first British legislation concerned with plant health. It referred only to the Colorado Beetle, and it controlled the importation of potato plants, or tubers, and other vegetables from anywhere outside the UK. It authorized destruction of a crop on which the beetle was found, and stipulated various control measures to be taken in the event of finding an infestation. It was changed to the Colorado Beetle Order in 1933.

The first established colony of Colorado Beetle in the UK was found in Kent in 1901, but it was successfully eradicated; since then there have been more than 120 breeding colonies found in parts of Kent and S.E. England, but prompt action by MAFF staff has ensured that none became established.

Similar introductions occurred in Europe, and in 1921 the pest became established near Bordeaux in France. It gradually spread throughout much of Europe, aided in part by the confusion caused by World War II. Fig. 10 shows the recorded spread of infestation of Colorado Beetle in Europe from 1921–61 (MAFF, 1961). Since then it has spread further in Continental Europe, and recently successfully invaded southern Sweden (see map on page 303), though after rigorous preventative measures it was contained and finally eradicated so that Sweden is once again free from this pest.

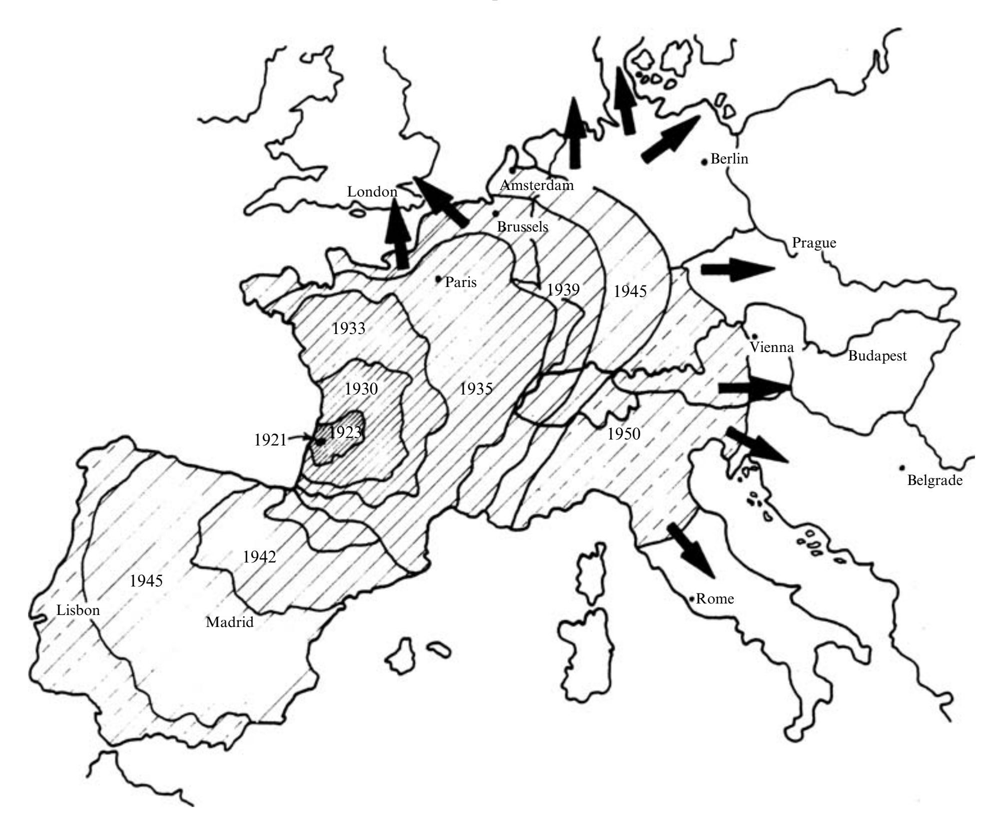
Colorado Beetle is restricted to plants of the Solanaceae as hosts, and it is particularly damaging to potato crops; infested crops seen in Europe often suffer complete defoliation if insecticides are not used.

An important pest of stored grains is *Trogoderma granarium* (Khapra Beetle, see page 276), now almost worldwide in distribution but still not established in parts of S. and E. Africa. Regular accidental introductions occur, usually from cargo ships carrying infested grain, but very strict examinations and control measures are taken to ensure that there is no spread of infestation beyond the dockside areas, and also that the infestation is soon destroyed. This pest was established in the USA in 1952, when it rapidly spread throughout the country, but it is now largely contained at a very low level by regular produce inspection and fumigation.

Fruit flies (*Dacus* and *Ceratitis* spp.; Tephritidae) are very important pests of most tropical fruits and a serious threat to *Citrus* (and other fruit) cultivation in both Florida and California (USA). There are regular accidental introductions of Medfly (*Ceratitis capitata*) into both areas, and on each occasion legislation has ensured an immediate eradication programme involving compulsory intensive widespread insecticide spraying both from the ground and from the air. To date, these campaigns have proved successful and the Medfly (and some other Tephritidae) have been denied establishment. The cost of eradication of a pest such as the Medfly (caught before it has spread very far afield) is quite infinitesimal in comparison with the value of the $14 000 million fruit industry in California.

An important publication on this topic is *Plant Health* (The scientific basis for administrative control of plant diseases and pests), edited for the Federation of British Plant Pathologists by Ebbels & King (1979).

Fig. 10. Approximate lines of advance of the Colorado Beetle in Europe since 1921.



Physical methods

These refer to methods of mechanical removal or destruction of the pest, and are usually unimportant in most countries owing to the high cost of labour. They are still of use in some countries and for particularly valuable crops.

Mechanical

Hand-picking of pests was probably one of the earliest methods of pest control and is still a profitable method for the removal of some caterpillars from young fruit trees. The killing of longhorn beetle larvae boring in branches of some bushes is recommended by the pushing of a springy wire (e.g. bicycle spoke) up the bored hole and spiking the insect. The use of mechanical drags, which crush insects on the ground, has been made against armyworms (*Spodoptera* larvae), but this practice is now generally outmoded. Banding on fruit trees is particularly effective against caterpillars and ants, which gain access to the tree by crawling up the trunk. Spray-banding of the apple trunks is practised against the wingless females of Winter Moth and other Geometridae which typically climb the lower parts of the trunk from the soil. An earlier method of locust control was to herd the hoppers into a large pit which was afterwards filled in with soil. Armyworms when on the move can often be trapped in trenches dug across their line of marching, and when trapped they are easily destroyed by burning, filling the trench or spraying with chemicals.

In parts of Asia, especially in gardens and on smallholdings, it is common practice to place bags around large fruits (e.g. grapefruit, pomelo, pomegranate and jackfruit) to deter fruit flies (Tephritidae) from oviposition. In rural areas and in the forests the bag is usually woven from grass or raffia, but in more suburban situations paper bags and polythene may be employed. Occasionally a single fruit may be left unprotected so that the local fruit-flies will concentrate their egg-laying upon this one fruit which can later be destroyed.

In temperate smallholdings and gardens it is a common practice to build a large cage of wire or string (now often plastic) netting over a fruit bed, but this protection is usually against fruit-eating birds rather than insects; such a cage may be portable and temporary or may be a permanent construction. This idea is now being developed on

Fig. 4.1. Guava fruits protected from fruit flies by bagging; Thailand.



Fig. 4.2. Platform at edge of maize field for boys to sit and scare away bird pests, and thieves.



quite a large scale throughout the world, particularly for the protection of seed-beds and also for particularly valuable crops that may be at risk locally (e.g orchids, etc.). Fig. 4.4 shows a protected area of seed beds, about 5 × 10 m, in Sarawak, for the rearing of virus-free *Brassica* seedlings and other crops. The netting is a fine plastic mesh and will keep insects as small as aphids at bay; if the mesh is too small however, plant growth may be retarded somewhat due to reduced sunlight levels. Small structures such as this are ideal for rearing seed crops of vegetables, and then insects such as blowflies (Calliphoridae) can be introduced inside the netting and maximum pollination may be easily achieved. These structures also provide some physical protection from strong winds, frost, heavy rain and extreme insolation, but do allow free air ciruclation which prevents over-heating, which makes these structures very useful for the tropics. They are particularly effective for rearing virus-free seedlings, for with care the aphid vectors (and others)

Fig. 4.3. Paddy field with cloth strips, etc., to scare birds away from the ripening crops; Sarawak.



Fig. 4.4. Protected seed beds in a cage of plastic mesh, 0.5 ha in area, also used for vegetable production; Sarawak.



can be completely excluded. Fungal spores will, of course, pass freely through the mesh.

Greenhouses in temperate situations provide complete physical protection for a crop, but the main purpose is to modify the temperate climate to provide a suitable hot/moist microclimate for the cultivation of exotic crops or local crops out of season. Nowadays the use of polythene tunnels has become very widespread (fig. 4.5) as these are effective and much cheaper to erect than the traditional glasshouses. The cultivation of protected crops has now become very sophisticated and in many respects is a separate branch of horticulture. In the UK the main source of expertise and information lies with GCRI (Glasshouse Crops Research Institute) at Littlehampton, Sussex. (There are similar institutions in other countries.) It is in these places where biological control of pests is widely practised, within the controlled microhabitat, with great success.

As long ago as a hundred years it was reported that discs made of tarred-felt could protect cabbage transplants from Cabbage Root Fly attack, and recent work at NVRS has shown that foam rubber (carpet underlay) discs of 12 cm diameter, placed around the stem of transplants, significantly

Fig. 4.5. Polythene tunnels used both for seedbed protection and crop production (vegetables, fruit, flowers, etc.).





reduced the level of Root Fly damage. This reduction in damage is due partly to the reduced numbers of eggs laid (only half the number) on the discs, and in part due to aggregation of predatory ground beetles under the discs, which consequently eat proportionally more fly eggs.

Use of physical factors

The use of lethal temperatures, both high and low, for insect pest destruction is of importance in some countries. (Often high temperatures are lethal for temperate pests, and low temperatures for tropical pests.) The use of cool storage in insulated stores for grain is practised in Asia and Africa. The purpose of this method is not the actual destruction of the pests, which may occur when lethal temperatures are employed, but the drastic retardation of development following the reduction of the metabolic rate.

Kiln treatment of timber for control of timber pests is very widely practised in many countries. Plant bulbs are often infested with mites, fly larvae (Syrphidae) or nematodes, and hot-water treatment (dipping) can be a very successful method of control if carefully carried out. The drying of grain, which is widely practised for a reduction in

moisture content, usually results in lower infestation rates by most pests. The heating of cotton seed to kill the larvae of Pink Bollworm (*Pectinophora gossypiella*) is an effective control. In different parts of the World hermetic storage of grain is being developed as a standard long-term storage method. The stores are now of several different basic types and generalization is not feasible; the principle involved is that only a small quantity of air is enclosed within the sealed bin, the oxygen in which is quickly used up by the respiration of the pests and the subsequent carbon dioxide accumulation quickly results in the death of all contained pests, both arthropod and microbial.

On-farm storage of grain is being carried out in some areas using butyl silos; the addition of small quantities of diatomite fillers increases the effectiveness of this control, as the abrasive effect removes the outer waxy covering of the epicuticle of the insects, resulting in greater water loss (and possible dehydration) and greater ease of insecticide penetration through the cuticle.

Use of electromagnetic energy

The radio-frequency (long wavelength radiations) part of the spectrum has been extensively studied in the development of radio communications, radar, etc., and it has been known for a long time that absorption of radio-frequency energy by biological material results in heating of the tissues. Control of insect pests by such heating is only practicable in enclosed spaces of small or moderate size (food stores, warehouses, timber stores). The nature of absorption of radio-frequency energy by materials in a high-frequency electrical field is such that for certain combinations of hosts and insect pests their dielectric properties are favourable for differential absorption of energy, hence the insects can be killed without damaging the host material. Timber beetles in wood blocks have been killed in this manner, but whether this treatment offers any real advantage over normal kiln treatment is doubtful.

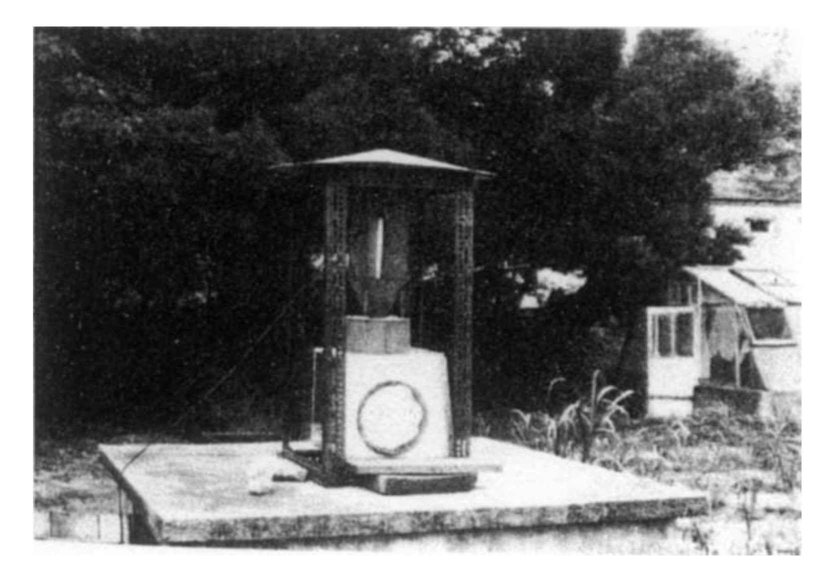
Use of infrared radiation for heating purposes is very much in its infancy.

Many insects show distinct preferences for visible radiation of certain wavelengths (i.e. certain colours), as well as the long recognized attraction of ultra-violet radiation for various nocturnal insects, especially Lepidoptera. Ultra-violet light traps have, on occasions, significantly lowered pest populations in various crops, but have also failed when used against other pests. Mercury vapour lamps are mostly being used for pest monitoring, especially for various night-flying Lepidoptera (Codling Moth, Pea Moth, rice stem borers, etc.), and for this purpose their use is now very widespread. In some countries, such as China, electricity lines are laid extensively throughout agricultural areas and ultra-violet light traps are used in large numbers (fig. 4.6).

Aphids and some other plant bugs are attracted to yellow colours; this is possibly because most aphids feed either on young or senescent leaves, presumably because these are the plant parts where active transport of food material occurs. The young leaves are photosynthesizing rapidly and the sugars formed are transported away in the phloem system to be stored as starch grains in older leaves, tubers, etc. As leaves become senescent, the stored starch is reconverted into soluble sugars for transportation prior to leaf dehiscence. Senescent leaves are usually yellowish in colour and young foliage is often a pale yellowish-green. So the attraction of aphids to yellow colours seems fairly obvious, but why so many flies (especially Anthomyiidae) and some months are similarly attracted to yellow is not obvious.



Fig. 4.6. Light trap in vegetable field for pest population monitoring; S. China.



This attraction for the colour yellow by so many insects is exploited in the use of many different types of trap; yellow water traps consistently catch more aphids and more Cabbage Root Fly adults; sticky traps coloured yellow, and even pheromone traps for Tortricoidea and Tephritidae, are often more effective than white ones. In a monitoring programme, it is of course necessary to make allowance for any enhanced trapping effect due to the colour of the trap.

Conversely, many flying insects are repelled by blue colours and by reflective material. This has been exploited by using strips of aluminium foil, or metallicized plastic, between the rows and around the periphery of the crop, the result being that fewer flying aphids and other insects settle in the crop than would otherwise. Thus, reflective strips also result in crops having far less aphid-borne virus diseases. Another effective method is to surround the seed-beds by flooded furrows, as practised in S. China with vegetable crops.

The ionizing radiations (X-rays, γ-rays) are sterilizing at lower dosages but lethal at higher. The use of these radiations in controlling stored product pests, particularly in grain, is being quite extensively studied in various countries.

Cultural control

These are regular farm operations, that do not require the use of specialized equipment or extra skills, designed to destroy pests or to prevent them causing economic damage. Often these are by far the best methods of control since they combine effectiveness with minimal extra labour and cost.

Most of the cultural methods do not give high levels of pest control, and in the recent past, when reliance was placed almost entirely on chemical control (using organochlorines), these methods received little attention. However, with the recent interest in integrated pest management there is a revival of interest in the use of cultural methods for incorporation into management programmes. Often the present-day scheme is to use several different methods in conjunction, each method achieving a certain level of control, so that in concert the desired level is achieved with minimal ecological disruption etc.

Optimal growing conditions

A healthy plant growing vigorously has considerable natural tolerance to pests and diseases (as with a healthy animal), both physically and physiologically. Good plant vigour is a result of sound genetic stock and optimal growing conditions. Obviously the farmer attempts to provide such growing conditions so that the crop yield will be maximal. Many diseases are more severe, and the damage by pests more serious, if the plant is suffering from water-stress (drought), unfavourable temperature, imbalance of nutrients or nutrient deficiency, etc. This *predisposition* to pest attack and disease can be very serious when crops are grown on marginal land. This is one main reason, together with reduced yield, why the cultivation of marginal land is generally not very successful.

This point is of particular interest at the present times, for various countries are endeavouring to increase their national agricultural yield, partly to produce more food crops to feed the ever-increasing population, and partly to increase the cash crops as a source of national revenue. But the great majority of countries are already utilizing all their high-quality agricultural land and the only land available for agricultural development is marginal tracts with a very limited potential. In some countries this situation is exacerbated in that land has to be taken from agriculture in order to provide sites for new towns, airports, and the general ever-increasing sprawl of urbanization; such land is almost invariably choice agricultural land, and may be the finest such land in the country (that being the main reason for the historical siting of the town in that location).

Photosynthetic efficiency

When aiming at a maximum level of sustained crop yield it is advantageous to understand the physiology of the crop plant in order that cultivation be practised in the most effective manner. This is also important in some countries where cultivation of marginal land is being undertaken, for only certain crops give adequate yields on poor land. Plants struggling in poor growing conditions are invariably more susceptible to damage by pests.

Some plants are now known to have a more efficient photosynthetic activity than others. They are referred to as C_4 plants – so named because of the chemical intermediary, the four-carbon oxaloacetic acid. The majority of plants, which could be called the 'normal' plants, are referred to as C_3 plants, C_4 plants generally have a high productivity in situations of high temperature and low humidity (and the concomitant low carbon dioxide concentration). They have a high level of stomatal resistance, which conserves water at high temperatures, but of course restricts carbon dioxide entry, but they are able to carry out photosynthesis very effectively under low carbon dioxide concentrations. As a group these plants are generally the most productive agriculturally. Examples of C_4 plants include maize, sugarcane and other tropical Gramineae as well as many weed species in the Chenopodiaceae, Euphorbiaceae, etc.

The more effectively functioning plants are generally those with the highest agricultural yields, and are also often more tolerant of insect attack and less susceptible to damage.

The importance of shade has been somewhat misunderstood in the past; several crops have in the past been thought to require shade for best growth and production; in some cases because they are naturally occuring forest understorey plants and to be regarded ecologically as skiophytes (i.e. shade-tolerant). A striking example is tea – for some obscure reason tea was thought to need shade, and many plantations bear mute testimony to this previous practice in the large number of dead trees to be seen standing throughout the plantation. Recent experiments in Indonesia have shown that cocoa grown as a heliophyte (i.e. fully exposed

to sunlight) gives a greater yield than when grown as usual under the shade of a tree cover. In the wild this shrub is a skiophyte adapted for life as a rain forest understorey shrub; but this adaptation to a low light intensity does not necessarily imply that it prefers shaded conditions. And the practice of growing cocoa as a forest-edge crop, under the shade of the trees, frequently exacerbates the pest situation in that many of the more serious pests live on (or in) the forest trees and continually invade the crop plants from this vast natural reservoir. In parts of Africa the most serious pests to ripening cocoa are the local monkeys, and in the forest these animals are almost impossible to control economically.

In Europe it has long been realized that strawberry plants grow and yield best when fully exposed to sunlight, even though they are found wild as woodland ground flora.

To minimize pest damage to agricultural crops it might be advantageous to review cultivation methods to determine that each crop is really being grown under optimum conditions, and not just to continue cultivation practices on the grounds of historical precedent.

Avoidance

Empirical observations will reveal that certain areas (and fields) are constantly 'at risk' from particular pests and conversely others are pest-free. Clearly, if a crop can be grown in areas of the latter category it can be expected to remain free from that particular pest. This practice is particularly effective against certain soil-borne diseases and nematodes, but less so against most insects because of their greater mobility. This is one of the advantages of shifting cultivation, so widely practised in parts of the tropics. Soil insects, such as root maggots (Anthomyiidae), wireworms, chafer grubs, rootworms (USA) and swift moth caterpillars, can to some extent be avoided by the planting of non-susceptible crops and the growing of the vulnerable crops at some distance away. Such practice is to be highly recommended, but is sometimes difficult to achieve as there may be strong agricultural, or other, reasons for growing the crops in those areas. Thus in the UK the East Anglian fenlands are ideal for growing carrots, celery and parsnip, but many of these areas have endemic Carrot Fly populations on the native hemlock and other Umbelliferae, and have long been areas highly 'at risk' from Carrot Fly. In this situation it is possible to minimize the risk from this pest by using other cultural methods such as crop rotation, etc., and of course chemical protection has to be used.

Time of sowing

By sowing early (or sometimes late) it may be possible to avoid the egg-laying period of a pest, or else the vulnerable stage in plant growth may have passed by the time the insect numbers have reached pest proportions. Early sowing is regularly practised against Cotton Lygus (*Taylorilygus vosseleri*) and Sorghum Midge (*Contarinia sorghicola*) in Africa. In N. Thailand it has been shown that early transplanting of paddy rice reduced the level of Rice Gall Midge attack appreciably. Another important aspect of the time of sowing is that of simultaneous sowings of the same crop over a wider area, to avoid successive plantings which often permit the build-up of very large pest populations.

In Europe the recent trend towards autumn-sowing cereals (winter wheat, winter barley) has reduced the risk of aphid damage to seedlings to a negligible level. At the same time this practice does increase the risk from Wheat Bulb Fly. Autumn-sown field beans are generally not at risk at all from Black Bean Aphid, whereas the spring-sown plants may be severely damaged.

With Wheat Bulb Fly only the very early-sown spring wheat is at risk, so if spring wheat is sown later there is little risk from this pest; but if sowing is delayed too much then crop growth is impaired!

Deep sowing (planting)

Some seeds are less liable to damage and pest attack if rooted deep, but of course if planted too deep germination will be impaired. Many root crops are also less liable to attack by pests if they are deeper in the soil. This is true for sweet potato in that the deeper tubers always have fewer weevils (*Cylas* spp.) boring inside, and the deeper potatoes have fewer infestations of Tuber Moth larvae. Even if no special attempts at deeper planting of root crops are made, then care should be taken to ensure that no tubers are allowed to grow too close to the soil surface; earthing-up should be done when required. Exposed root crops may be damaged by pheasants, other birds, and by rodents and rabbits grazing.

Time of harvesting

Prompt harvesting of maize and beans may prevent these crops from becoming infested by Maize Weevil (*Sitophilus zeamais*) and Bean Bruchid (*Acanthoscelides obtectus*) respectively. Both of these pests infest the field crops from neighbouring stores, but are generally not able to fly more than about half a mile; so an added precaution is to always grow these crops at least half a mile away from the nearest grain store.

New varieties of crops which mature early may enable a crop to be harvested early, before pest damage is serious. This is one of the qualities that many plant breeders are constantly seeking in a very wide range of different crops. This approach requires detailed knowledge of the ecology and life history of the local serious pests so that crop development might be desynchronized in relation to pest population development.

Close season

In E. Africa legislation has been passed to ensure that there is a close season for cotton growing in order to prevent population build-up of Pink Bollworm (*Pectinophora gossypiella*) which is oligophagous on Malvaceae. This legislation stresses that all cotton plants should be uprooted and destroyed (or burned) by a certain date and quite clearly no seed would be planted until the following rains arrive. However, it is clear that many farmers do not bother to destroy the old plants by the appointed date and so in some areas there is considerable survival of diapausing Pink Bollworm larvae.

This approach to pest control tends to be more applicable to the tropics where insect development and crop production may be more or less continuous. In temperate regions there is already established very firmly a close season for virtually all crops, namely winter!

Deep ploughing

Many Lepidoptera (particularly Noctuidae, Hepialidae, Sphingidae and Geometridae), Coleoptera and Diptera pupate in the soil, and a large number of their larvae live there. The bulk of the soil insect population lie in the top 20 cm of the soil (most are in the top 10 cm). Deep ploughing will bring these insects to the surface, to be exposed to hot sunlight (insolation), desiccation and predators. In many tropical areas a farmer ploughing a field will be followed by a flock of cattle egrets, little egrets, crows or starlings, in a seaside locality there might be a flock of gulls; all these birds will feed on the exposed worms, slugs and insects. In temperate regions a plough is usually accompanied by a large flock of birds (gulls, crows, etc.), and although the birds are also eating earthworms their consumption of insect larvae and pupae (many or most of which are pests) must be prodigious, as often a hundred or more birds may follow a single tractor.

Fallow

Allowing a field to lie fallow almost invariably reduces pest and pathogen populations, but care must be taken to ensure that there are no volunteer crop plants or important secondary host weed species. Fallowing may be done as *bare fallowing* when the soil surface is left bare, or *flood fallowing* when the field is flooded with water for a while. Sometimes, as an alternative, a cover crop of legumes is grown as *green manure* which is then ploughed under.

Set-aside

A recent development in Europe is the practice of set-aside where fields are left uncultivated for a year or more; and the farmers are compensated financially by the government.

Crop rotation

In olden times a period of fallow was an essential part of all crop rotations, but nowadays economic pressures mean that fields can seldom be left fallow. Instead, basic crop rotation is usually practised for the obvious reasons that continuous cultivation of one crop depletes the minerals and trace elements in the soil quite rapidly, and also induces disease and pest build-up. However, some agricultural crops require rather specialized growing conditions, and these, combined with the practice of large-scale cultivation, result in some areas growing crops such as sugarcane, wheat, pineapple, maize or potato, almost continuously. Obviously the orchard crops (apple, plum, pear, citrus, peach, olive, etc.) are also very long-term monocultures, as are vineyards.

The alternation of completely different crops in a field has very obvious advantages from the pest and disease control aspects. But in a rotation it is necessary to remove a particular crop quite a distance away; having the same crop in an adjacent field is not really 'rotation' so far as active insects are concerned, although it might be adequate for soil nematodes and some soil-borne diseases. So, for effective pest control crop rotation has to separate crops both spatially and in time (temporally).

Against monophagous and oligophagous pests crop rotation can be effective, especially with beetle larvae that may take a year or more to develop, but it is not effective against migratory pests or those with effective powers of


Fig. 4.7. Little Egrets following a plough in Ethiopia.



dispersal. The alternation of cereals with non-cereals may be an important method of curtailing *Nematocerus* weevils in Africa. A common type of rotation is the alternation of a legume crop with cereals; this is effective against some pests, but others (e.g. *Colaspis*, *Diabrotica*) can utilize both host types. In Europe a combination of potato, wheat and rape is currently popular and successful.

Secondary hosts

Most pests are not monophagous and so will live on other plants in addition to the crop. Sometimes, in point of fact, the crop itself is not the preferred host! For example, Turnip Aphid is often more abundant on *Cardamine* and charlock, etc., than on the *Brassica* plants. In many cases the pests build up their numbers on wild hosts and then invade the crop when the plants are at the appropriate stage of development. Many Cicadellidae and Delphacidae that are crop pests (on rice and other cereals) feed and breed on wild grasses in the vicinity of the paddy fields so that when the young rice is planted out there is a large bug population waiting to infest the young tender shoots of the rice. The destruction of alternative hosts (or the control of insects on them) may be an important part of an IPM programme. The alternative hosts are usually native plants (but may be introduced), and may be trees, shrubs, or herbaceous plants; they may be cultivated species, wild plants or weeds. Solanaceous weeds, for example, are important alternative hosts for pests of tomato, tobacco, eggplant and potato. In many cases the permanent pest population in an area is maintained not on crop plants but on wild plants belonging to the same family; there are many wild Cruciferae that support *Brassica* pests and the number of wild Leguminosae, Chenopodiaceae, Rosaceae, etc., is very large.

In temperate situations a number of pests and diseases have an alternation of generations on quite different hosts, e.g. *Myzus persicae* on peach and potato. The removal of the alternative host can effectively reduce such pests to insignificance, but in the case cited, of course, the alternative host is itself a crop plant. Black Bean Aphid overwinters on spindle trees, and in some areas attempts have been made to remove these trees locally, but usually without much success. *Pemphigus bursarius* overwinters on poplar trees where it makes petiole galls in the spring; later generations migrate to lettuce where they encrust the roots.

With monophagous pests it is important to remove any host plants between crops (if feasible for the species concerned). A monophagous insect would normally be confined to the species of a single genus for host, though it would be unusual for it to be restricted to a single species of one genus. Thus, for sugarbeet pests it is not feasible to attempt to remove all wild species of Chenopodiaceae as they are too abundant. But, for the Brown Planthopper of Rice (*Nilaparvata lugens*) which is restricted to rice (*Oryza* spp.) as a host plant, the alternative host plants are either wild rice or volunteer rice; by destruction of wild rice weeds, volunteer plants and crop residues, this pest can be partially controlled.

The situation with regard to secondary/alternative hosts tends to be more important in the tropics where usually there are more wild plants in the immediate neighbourhood of the crop, especially where land is cultivated along the edges of tracts of native forest ('jungle').

Weeds

Most cultivation practices require destruction of weeds because of their competition with the crop plants, and their interference with different aspects of cultivation. But weeds can also be important from the viewpoint of pests and diseases; sometimes the weeds may be alternative hosts, as already mentioned. Weeds in a particular crop often belong to the same family as the crop plant because of the selective nature of many post-emergence herbicides. Some pests seem to prefer weeds as oviposition sites; for example, some cutworms (*Agrotis* spp.) and some beetles (Scarabaeidae) lay most of their eggs on, or in the immediate vicinity of, weeds in the crop. Weed removal at the appropriate time may result in many potential pests being destroyed. Some weeds are important as natural reservoirs (alternative hosts) of both pathogens and invertebrate pests.

Trap crops

The use of trap plants to reduce pest infestation of various crops is based upon the knowledge that many pests actually prefer feeding upon plants other than those on which they are the most serious pests. This preference may be exploited in two different ways: either the pests are just lured from the crop on to the trap plants where they stay and feed, or else, because of the greater concentration of pests on the trap plants, only the trap plants need be sprayed with pesticides. In the latter case, since the trap plants are either grown as a peripheral band or else interplanted at about every fifth to tenth row, the saving of insecticide represented is considerable.

This is a technique used mostly in warmer parts of the world where insect pest breeding is more or less continuous; in the cooler temperate regions, with the cold dormant winter period, it is of less applicability. The practice of intercropping is based upon the same premise, and this has long been a regular method of reducing levels of pest damage in Europe and N. America.

Intercropping

This practice obviously has various drawbacks for large-scale agriculture, but can be of particular application for the small farmers, who often use little insecticide. Intercropping can certainly reduce a pest population on a crop, and without doubt reduces the visual and olfactory stimuli that attract insects to a particular crop species. As a method of control it is most effective against exogenous pests, such as locusts, which enter the crop for only part of their life-cycle. In N.E. Thailand in 1980 groundnuts were inter-cropped with maize, and nymphs of Bombay Locust (*Patanga succincta*) were induced to leave the maize (particularly on hot days) for

the lower foliage of the groundnuts where they were eaten by ducks. Work is in progress on different schemes of intercropping at IRRI in the Philippines, for use particularly in that country with its large proportion of peasant farmers.

In Europe, on smallholdings, it has long been a regular practice to intercrop, often using plants with very strong odoriferous qualities in the hope that the odours released would confuse the host-seeking female insects, which it does appear to do. Onions and crucifers, for example, would be used to shield carrot crops. Often wildtype plums are grown around the periphery of apple orchards where they act partly as a wind shield and also as a diversion for a number of different insect pests.

Crop sanitation

This is a rather general term, and usually is used to include the following different aspects of crop cultivation.

(a) Destruction of diseased or badly damaged plants – the roguing of such plants is an important agricultural practice, but of course requires hand labour. For agricultural crops this is sometimes not feasible, but some farmers do make the necessary effort; with horticultural crops such as fruit orchards, flowers and some vegetables, destruction (preferably by burning) of infected and infested branches etc., is an important aspect of any control programme, as it is easier to remove the foci of infection than to kill the organism with pesticides.

(b) Removal and destruction of rubbish – old crop remnants, fallen leaves, branches, dead trunks, also weeds, etc. Some pests use rubbish heaps for breeding purposes, for example scarab larvae are to be found in rotting vegetation and soil, especially in rubbish heaps. The tropical *Oryctes* beetles are good examples, as the larvae are found in rotting palm trunks and rubbish heaps.

(c) Removal and destruction of fallen fruits – for the control of many fruit flies and boring caterpillars this is important, as the insects will continue to develop in the fallen fruit and will pupate either there or in the soil. This is, in fact, still a successful method for reducing the numbers of Codling Moth and other fruit-boring caterpillars, as well as for many different fruit flies (Tephritidae). It is still one of the best methods of control for Coffee Berry Borer, where labour permits.

(d) Destruction of crop residues – this is often vitally important in order to kill the resting stages (pupae, etc.) of many pests after harvest. Many stalk borers (Pyralidae, Noctuidae) pupate in the lower parts of the cereal stems and as such will be left in the stubble even if the main parts of the stalks are removed. With some crops of maize, sorghum and millets most of the actual stem is left. The stems should be burnt immediately after harvest. The rotting residues of crops such as turnip, parsnip and *Brassica* generally, after being ploughed in attract ovipositing female Bean Seed Fly and other Muscoidea. For diseases, crop residue destruction may be even more important. Ploughing in of crop stubble may kill a small proportion of pupae but most will survive; burning is most effective. European Corn Borer traditionally overwinters in maize stubble, but most farmers are now aware of this and so the stubble is destroyed.

The recommended method of destruction of all weeds, crop residues, rubbish, rogued plants, fallen fruits, etc., is by collection and burning; other methods may not kill the pests.

Crop sanitation tends to be a term mostly used by plant pathologists rather than entomologists, as it aims mostly at the removal of sources (foci) of disease infection.

Crop plant resistance to pest attack

In most growing crops it may be observed that some individual plants either harbour far fewer pests than the others or else show relatively little sign of pest damage. These individuals usually represent a different genetic variety from the remainder of the crop, and this variety is said to show *resistance* to the insect pest. Also when different varieties of the same crop are grown side by side, differences in infestation level may be very marked. Resistance to pest attack is characterized by the resistant plants having a lower pest population density, or fewer damage symptoms, than the other plants which are termed *susceptible*. Conversely, there will be some plants that appear to be preferred by the pests and these especially susceptible plants will bear very large pest populations. Frequently these plants will actually be destroyed by the pests and so will not breed and pass on their disadvantageous genetic material.

The main use of resistant varieties of crop plants in agriculture has been against plant diseases (Russell, 1978), and in general a high level of success has been achieved. Plant-parasitic nematodes (eelworms) in some ways behave rather like soil pathogens, and the development of resistant varieties of potato and wheat have been very successful in combating Potato Cyst Eelworm and Cereal Root Eelworm. Against insect pests plant breeding for resistance has not had the same success, but in some instances good control has been achieved with enough success to encourage further work in this area. On the whole it can be said that many resistant varieties of crop plants have given quite good control of insect pests, albeit only partial, against a very wide range of insect species. Many varieties of crop plants showing good resistance to important pest species have not been fully exploited because their yield is less, or of inferior quality, than the usual susceptible varieties.

In January, 1984, the Royal Entomological Society of London had a paper presented on the topic of ‘Hypotheses concerning the evolution of plant resistance to insects’ by

Dr P.P. Feeny, illustrated mostly by reference to swallowtail butterflies and their food plants.

Varietal resistance to insect pests was broadly classified by Painter (1951) into three categories: non-preference, antibiosis, and tolerance; but Russell (1978) suggests the use of a fourth category: pest avoidance. Some workers restrict the use of the term varietal resistance to antibiosis, but this view is rather narrow and not practical. In fact it is often very difficult to distinguish between some cases of non-preference and antibiosis.

Types of resistance

(a) Pest avoidance
(b) Non-preference (= non-acceptance)
(c) Antibiosis
(d) Tolerance

The basis of these types of resistance is slight variations in genetic material; as defined by Russell (1978), 'Resistance is any inherited characteristic of a host plant which lessens the effect of parasitism.' The term *parasitism* is used in a broad sense to include the attack of insect pests, mites, vertebrates, nematodes, and pathogens (fungi, bacteria, viruses) on the host plant. The feeding of phytophagous insects on plants is not generally regarded as parasitism by most zoologists, but rather as ecological grazing.

Genetically there are three main types of a resistance. *Monogenic* resistance is controlled by a single gene, usually a *major gene* which has a relatively large effect. This type of resistance (often biochemical, involving phytoalexins) is fairly easily incorporated into a breeding programme, and it usually gives a high level of resistance; unfortunately this resistance is just as easily 'broken' by new pest 'biotypes' (new races or strains).

Oligogenic resistance is the term used when the character is controlled by several genes acting in concert.

Polygenic resistance is the result of many genes, and is clearly more difficult to incorporate into a plant breeding programme. It may be either morphological or biochemical, and it is generally less susceptible to biotype resistance ('breaking'). Many of the genes will be *minor genes* which individually only have a small effect genetically.

In epidemiological terms, resistance is classified as either *horizontal resistance* (alternatively, durable resistance), with a long-lasting effect and effective against all genetic variants of a particular pest, or *vertical resistance* (alternatively, transient resistance), effective for a short period and against certain variants only.

There are a few other terms which are in use in plant breeding for pest resistance. *Field resistance* is the term used commonly to describe resistance which gives effective control of a pest under natural conditions in the field, but is difficult to characterize in laboratory tests; usually it is a complex kind of resistance giving only partial control. *Passive resistance* is when the resistance mechanism is already present before the pest attack, for example an especially thick cuticle, or hairy (pubescent) foliage. *Active resistance* is a resistance reaction of the host plant in response to attack by a parasite more usually applicable to attack by pathogens rather than pests (insects etc.); for example, the formation of phytoalexins or other antibiotics (antifungal compounds) by some host plants in response to attack by some pathogenic fungi. This reaction is not unlike the human production of antibodies in response to foreign matter in the blood or tissues. *Qualitative resistance* applies when the frequency distribution of resistance and susceptible plants in the crop population is discontinuous, and the plants are individually easily categorized as either resistant or susceptible. *Quantitative resistance* is the term used when a crop shows a continuous gradation between resistant plants and susceptible plants within the population, with no clear-cut distinction between the two types.

Varietal resistance has been shown in a broad range of crop plants ranging from cereals and herbaceous plants to trees, against an equally broad range of insect, mite and vertebrate pests. The insect groups involved include Orthoptera (locusts), Hemiptera (bugs), Lepidoptera (caterpillars), Diptera (fly maggots), Thysanoptera (thrips), and Coleoptera (beetles), in both temperate and tropical parts of the world.

In many respects crop plant breeding for pest resistance is the most ecologically desirable method to be employed in pest management programmes. The time factor is quite considerable in that a breeding programme is slow to conduct, and the cost may be exorbitant, but the end result could be very long-term control without the use of pesticides and their associated problems. At present there are a number of plant breeding programmes in operation in different parts of the world for different crops and different pests, some at major international research institutes. Some of the better known stations include IRRI, Philippines (rice), CIAT, Colombia (cassava, etc.), IITA, Nigeria (many tropical crops), Cotton Growing Corporation, Africa, India, etc. (cotton), PBI, England (potatoes, wheat), NVRS, England (vegetables), and many other stations specializing in fruit (UK, USA), sorghum (East Africa), maize (India), pulses (E. Africa and UK), and so on. The scope of some of these plant breeding programmes is often very large, for example at IRRI all 10 000 varieties of rice, representing the world germ plasm collection, have been screened for resistance to rice stalk borers. More than 20 varieties show high levels of resistance to *Chilo* caterpillars by non-preference and/or antibiosis mechanisms, and some of these varieties are also resistant to leafhoppers and planthoppers. Some of these varieties of rice show tolerance towards these pests, as well as definite antibiosis and non-preference.

It is, however, now clear that, in response to the development of new resistant plants, it must be expected that new insect biotypes will arise to which the existing plants are not resistant. Fortunately, it appears that most insect resistance in plants is complex and polygenic in nature, which may help to discourage development of insect biotypes.

Pest avoidance

This is when the plant escapes infestation by the plant not being at a susceptible stage when the pest population is at its peak. Some varieties of apple escape infestation by several different pest species in the spring by having buds which do not open until after the main emergence period of the pests, thus reducing the final amount of damage inflicted.

Non-preference (= Antixenosis)

The term 'non-acceptance' has been proposed as a more suitable alternative, but has never gained general acceptance. Insects are noticeably reluctant to colonize some individual plants, or some particular strain of host-plant, and these plants seem to be less attractive to the pest by virtue of their texture, colour, odour or taste. Non-preference usually is revealed when the bug or caterpillar either refuses to feed on the plant or takes only very small amounts of food, or when an ovipositing female insect refrains from laying eggs on the plant. In the Philippines *Chilo supressalis* females laid about 10–15 fewer egg masses on resistant rice varieties than on susceptible ones. Also at IRRI, the Brown Planthopper of Rice (*Nilaparvata lugens*) punctures the tissues of a certain rice variety but apparently feeds only little, probably because of the reduced amount of a particular amino acid (asparagine) in the sap of that variety. In Uganda, experiments at Namulonge (Stride, 1969) showed that Cotton Lygus Bugs (*Tayloriligus vosseleri*) found some red-coloured varieties of cotton less acceptable for feeding purposes than the usual green plants, and this difference in preference was attributed to the presence of certain aromatic compounds in the sap of the red-coloured plants.

Non-preference based upon the absence or presence of certain chemicals in the plant tissues or sap may equally well be categorized as a form of antibiosis.

Two temperate examples of this type of resistance include Raspberry Aphid (*Amphorophora idaei*) which when placed on to leaves of resistant plants exhibit a reaction so strong that they will quickly walk off the plants completely. On sugarbeet aphids do not actually walk off the resistant plants, but they do feed for noticeably shorter periods of time and are quite restless whilst on resistant plants. The precise details of the resistance in these cases is not yet known, but the insect reactions are easily observed.

Antibiosis

In this case the plant resists insect attack, and has an adverse effect on the bionomics of the pest by causing the death of the insects or decreasing their rate of development or reproduction. The resistant plants are generally characterized by anatomical features such as thick cuticle, hairy stems and leaves, a thickened stem (cereals), a narrower diameter of the hollow pith in cereal stems, compactness of the panicle in sorghum, tightness of the husk in maize, and tightness of leaf sheaths in rice. Biochemical aspects usually involve the presence of various toxic or distasteful chemicals in the sap of the tissues of the plant which effectively repel feeding insects, sometimes to the extent that the odour is sufficient to completely deter them from feeding. Alternatively, there may be a chemical which normally functions as a feeding stimulant missing from the body of the resistant plant, or else at a sufficiently low concentration that it fails to stimulate the insect into feeding behaviour.

Cotton Jassids (*Empoasca* spp.) have ceased to be important pests of cotton in Africa and India since the post-war development of pubescent strains which the bugs find quite unacceptable as host plants. In a similar manner, hairy-leaved varieties of wheat in N. America are attacked significantly less often by the Cereal Leaf Beetle (*Oulema melanopa*); the females lay fewer eggs on the leaves and, of the larvae that hatch, fewer survive. It is also recorded that pubescent foliage apparently deters oviposition by many species of Lepidoptera, but this situation is complicated in that some bollworms will apparently lay more eggs on the foliage of some pubescent varieties of cotton.

The tightness of the husk in some maize varieties will deter feeding on the cobs by larvae of *Heliothis zea* (Corn Earworm) in the USA, and should also apply to field infestations of the drying grain by Maize Weevil (*Sitophilus zeamais*). At IRRI it has been shown that the tightness of the leaf cleavage in rice varieties is closely correlated with resistance to stem borers. If the leaf sheath is tight and closed and covers the entire stem internode, the young caterpillars usually fail to establish themselves between the leaf sheath and the stem where they would normally spend some six days feeding before boring into the stem. Varieties of sorghum in Africa, with an open panicle, suffer far less damage by False Codling Moth (*Cryptophlebia leucotreta*) and other caterpillars. Wheat varieties with solid stems (i.e. very reduced pith) are noticeably resistant to Wheat Stem Sawfly (*Cephus cinctus*) in N. America in that growth and development of the larvae are retarded. Some species of pyralid and noctuid stemborers are closely restricted to cereal hosts with stems of a particular thickness, and varieties with thicker or thinner stalks may harbour fewer caterpillars.

An anatomical factor of considerable importance is the development of silica deposits in leaves and stems of various graminaceous crops. The Gramineae as a group are basically semixerophytic and so most species have silica deposits in the leaves and stems; not only the truly xerophytic species such as marram grass (*Ammophila* spp.), but also species which have become secondarily adapted as hydrophytes such as rice, still possess some deposits. A number of cereals are indigenous to semi-arid areas, and one example is sorghum. In these plants silica deposits are apparently formed in some resistant varieties at about the fourth leaf stage. Up to this stage most varieties of sorghum are attacked by Sorghum Shoot Fly (*Atherigona soccata*), but in the resistant varieties infestations are not usually recorded once these silica deposits are formed, although infestations will still occur in susceptible varieties up to the sixth

leaf stage. This is a simple type of resistance which is easily incorporated into all sorghum breeding programmes. A recent account of the role of silica in protection of Italian ryegrass from Frit and other shoot flies is given in Moore (1984).

The Hessian Fly (*Mayetiola destructor*) was introduced into the USA in the mid-18th century and rapidly became a major pest of wheat; the larvae attack the wheat stem, and either destroy the shoot or weaken the stem so that lodging subsequently occurs. Heavy attacks cause a serious drop in wheat yield. Since 1914 a search for resistance was carried out in Kansas. Several resistance varieties were developed, and since 1965 the widespread growing of resistant varieties has resulted in the virtual extinction of Hessian Fly in Kansas. Some 25 different resistant varieties of wheat are being grown in the USA now, and the annual value of the wheat crop has increased by many millions of dollars. The mechanism of resistance has not been established, but it is known that these resistant wheats have unusually large deposits of silica in the leaf sheaths.

At IRRI rice varieties have been developed with a high silica content in the leaves and stems, and these are resistant to larvae of *Chilo suppressalis* in that the caterpillars' mandibles become worn down by the abrasive nature of the silica deposits.

The biochemical factors involved in plant resistance arise from differences in the chemical constituents of the plants. The differences may be restricted to different parts of the plant body and/or particular stages in the growth of the plants. It is thought that in some resistant plants the pest concerned suffers nutritional deficiencies resulting from the absence of certain essential amino acids. Some maize varieties show direct physiological inhibition of larvae of the European Corn Borer (*Ostrinia nubilalis*) for they possess biochemical growth inhibitors at various stages. Some pests are influenced in their host selection by aromatic compounds present in the plant tissues, as well as various sugars, amino acids, and vitamins in the sap. Resistance to the Brown Planthopper of Rice by a rice variety at IRRI was attributed to a low concentration of asparagine, thought to be a feeding stimulant for this pest. Cabbage Aphid (*Brevicoryne brassicae*) is stimulated by sinigrin (a mustard oil glucoside) in the leaves, and it has been shown that a high level of resistance to Cabbage Aphid is associated with low foliar concentrations of sinigrin. Some cotton varieties have a poisonous polyphenolic pigment, gossypol, in subepidermal glands, and they show a strong resistance to several different insect pests (Pink Bollworm, Spiny Bollworm, etc.), although a direct causal relationship has not been established.

Members of the family Solanaceae often have peculiar glandular hairs on the leaves and stems, and recently new potato varieties have been obtained by crosses with various wild stocks from S. America which have an abundance of these glandular hairs. The sticky exudates easily trap small insects like aphids, which soon die, and even such large insects as larvae of Colorado Beetle have been trapped. This easily inherited character is hoped to be of value in combatting potato aphid attack, for these sap-sucking bugs are vectors of several major virus diseases. It was reported in 1982 that breeding programmes had been established at both PBI and GCRI in the UK to try to incorporate the 'hairy' attributes of the Peruvian varieties into the usual domestic varieties.

Many plants have evolved biochemical as well as physical methods of protection against grazing and browsing herbivores; this topic is reviewed more extensively in chapter 2 on pest ecology (page 13) but should be mentioned here. One common method of deterring grazers is shown clearly by both oak and beech in that the leaves are soft and tender for only a short time after bud-burst; after about a week sclerification is evident within the leaf tissues and at the same time various chemical substances (tannins) are accumulating in the tissues (page 13). The result is that various leaf-mining weevils (in beech) and caterpillars, such as Winter Moth (on oak), find the older leaves less suitable as food and larval mortality increases quite significantly (Bale, 1984). Apparently individual trees vary quite extensively in this respect, and may often be easily categorized as 'susceptible' and 'resistant' trees.

Tolerance

Tolerance is the term used when host plants suffer little actual damage in spite of supporting a sizeable insect pest population. This is characteristic of healthy vigorous plants, growing under optimal conditions, that heal quickly and show compensatory growth. In fact most plants bear more foliage than they actually need, and can usually suffer a fair amount of defoliation with no discernible loss in crop yield.

Tolerance is frequently a result of the greater vigour of a plant, and this may result from the more suitable growing conditions rather than from the particular genetic constitution of the plant. For example, sorghum growing vigorously will withstand considerable stalk borer damage with no loss of yield. Some varieties of crop plant (e.g. rice) may show both tolerance to a pest as well as antibiosis; this is true for several stalk borers.

Sometimes pest attack on a tolerant variety can actually increase the crop yield; this occurs quite frequently with the tillering of cereals following shoot fly, stem borer, or cutworm destruction of the initial shoot in the young seedling.

From a pest management point of view the use of a tolerant variety could in theory be a disadvantage in that it could support a larger population of the pest and so encourage a local population build-up rather than a decline.

Many cases of clear-cut resistance to insect pests have been recorded, but they have not been investigated sufficiently for the mechanism of resistance to be evident. This is particularly the case in respect to the aphids *Myzus persicae* and *Aphis fabae* on sugar beet, and to Carrot Fly (*Psila rosea*) on carrots (Hill, 1974*b*; Ellis *et al*., 1980).

Breaking of host plant resistance

In some agricultural situations there develop physiological races of the insect pest, known as *biotypes*, some of which are not susceptible to the host plant resistance. These are *resistance-breaking biotypes*. In nematology this type of variant is known as a *pathotype*, in virology it is a *strain* and, applied to fungi, it is a *race*.

The development of resistance-breaking biotypes has been known for a long time in the Hessian Fly, and several biotypes can attack wheat varieties that are quite resistant to other biotypes. The Brown Planthopper of Rice (BPH) in S.E. Asia has recently become notorious in that for several reasons it has changed status from a minor to a serious major pest on rice. However, rice varieties resistant to this bug were developed at IRRI, and have been widely grown throughout the area; they have given such good control that sometimes insecticides have not been required. In some localities, however, resistance-breaking biotypes of BPH have developed to such an extent as to threaten local rice production. The present situation is that as fast as the research workers at IRRI produce resistant varieties of rice to BPH, the insects correspondingly produce new resistance-breaking biotypes. Detailed biosystematic and ecological studies of the biotypes of *Nilaparvata lugens* have very recently been initiated at IRRI and through the auspices of the ODA in the UK.

The breaking of host plant resistance is generally less common amongst insect pests than pathogens. This is thought to be because insects produce far fewer propagules than the fungi, bacteria and viruses, and thus far less genetic variation can be expressed.

Biological control

In the broad sense (*sensu lato*) this can include all types of control involving the use of living organisms, so that, in addition to the use of predators, parasites, and disease-causing pathogens (biological control – *sensu stricta*), one can include sterilization, genetic manipulation, use of pheromones, and the use of resistant varieties of crop plant.

As already indicated in this book, the use of resistant crop varieties is being dealt with separately as it is an aspect of control of such importance, and plant breeding is a very specialized subject in its own rights. In chapter 6 biological control (*sensu stricta*) is considered in more detail, and here it is only intended to be introduced in its broadest aspects.

The main attraction of biological control is that it obviates the necessity (or at least reduces it) of using chemical poisons, and in its most successful cases gives long-term (permanent) control from one introduction. This method of control is most effective against pests of exotic crops which often do not have their full complement of natural enemies in the introduced locality. Then the most effective natural enemies usually come from their native locality, for the local predators/parasites/pathogens are usually in a state of delicate ecological balance in their own environment and cannot be expected to exercise much population control over the introduced pests. On rare occasions a local predator or parasite will successfully control an introduced pest, but this is rare!

Natural control

This is the existing population control already being exerted by the naturally occuring predators and parasites (and diseases) in the local agroecosystem, and it is vitally important in agriculture not to upset this relationship. Because it is not readily apparent, the extent of natural control in most cases is not appreciated. It is only after careless use of very toxic, broad-spectrum, persistent insecticides which typically kill more predators and parasites than the less sensitive crop pests, and which is then followed by a new, more severe pest outbreak, that the extent of the previously existing natural control may be appreciated. In summary, the importance of natural control of pests in most agroecosystems cannot be overemphasized.

Predators

The animals that prey and feed on insects are very varied, as are their effects on pest populations. The main groups of entomophagous predators are as follows:

Mammalia – (man), Insectivora, Rodentia
Aves – Passeriformes (many families), many other groups, especially ducks, game birds, egrets and herons, hawks
Reptilia – small snakes, lizards, geckos, chamaeleons
Amphibia – most Anura (frogs and toads)
Pisces – *Gambusia* etc. (control mosquito larvae)
Arachnida – spiders, harvestmen, chelifers, scorpions, etc.
Acarina – mostly family Phytoseiidae
Insecta – Odonata (adults, and nymphs in water), Mantidae, Neuroptera, Heteroptera (some Miridae, Anthocoridae, Reduviidae, Pentatomidae), Diptera (Some Cecidomyiidae (larvae), Syrphidae (larvae), Asilidae, Therevidae, Conopidae, etc.), Hymenoptera (Vespidae, Scoliidae, Formicidae), Coleoptera (Cincindelidae, Carabidae, Staphylinidae, Histeridae, Lampyridae, Hydrophilidae, Cleridae, Meloidae and Coccinellidae)

A few predators are quite prey-specific; for example, the larvae of Meloidae feeding on the egg-pods of Acrididae in soil, and Scoliidae feeding on scarab larvae in soil and in rubbish dumps. But most predators are not particularly confined to any specific prey. Some of the predators live in rather specialized habitats; for example, all the fish are aquatic, as are some insect larvae (e.g. Odonata), and so only prey on aquatic insects (such as mosquito larvae); some live

Fig. 4.8. Caterpillar with parasite cocoons on its body; Malaysia.



Fig. 4.9. Olive scale with chalcid parasite emergence hole; Ethiopia.



in soil or leaf litter so their prey is restricted to certain types of insects (more details are given in chapter 6).

Parasites

These are almost entirely other insects and belong to two large groups (Diptera and Hymenoptera) and one small group (Strepsiptera), together with a number of important species of entomophilic nematodes. The Diptera include the large family Tachinidae which parasitize Lepidoptera (larvae), Coleoptera, Hemiptera and Orthoptera. Other parasitic families include Phoridae, Pipunculidae, Bombylinidae, and there are some parasites in the Sarcophagidae and Muscidae.

The Hymenoptera include the very important Chalcidoidea and Ichneumonoidea, and some Bethylidae, Scelionidae and Proctotrupidae. Some groups of parasitic wasps are miniscule (being the tiniest insects known, about 0.2 mm in body length) and all are egg-parasites. Almost all groups of insects (as well as spiders and ticks) are parasitized by the Hymenoptera Parasitica, at all stages of development from egg to adult. Many species of parasitic wasps lend themselves to exploitation in biological control projects.

Pathogens

Control by pathogens is sometimes referred to as *microbial control*. There are three main groups concerned: bacteria, fungi and viruses, and some other groups of entomophagous micro-organisms which are rather obscure and little studied. There are several types of *Bacillus*, which are specific to caterpillars or beetle larvae, responsible for natural epizootics, and several species are now commercially formulated and very important in pest control projects.

Fungi are responsible for producing antibiotics and apparently about 300 antibiotics do show some promise as pesticides; these act directly as killing agents or inhibitors of growth or reproduction.

Viruses are quite commonly found attacking insects in wild populations of caterpillars and beetle larvae, as well as some temperate sawfly larvae. They have long been used as biological insecticides, by finding dead larvae in the field and making an aqueous suspension of their macerated bodies. But now a few commercial preparations are available.

Some of these new biological insecticides using insect pathogens are, however, only easily available in the USA as yet, although others are commercially available in Europe and parts of Asia.

Sterilization

This usually refers to the sterilization of males by X-rays or γ-rays and is called the *sterile-male technique*; control of a pest by this technique is termed *autocide*. Sterilization can be effected by exposure to various chemicals and this practice is called *chemo-sterilization*. The rationale behind this method is that male sterilization is effective in species where females only mate once and are unable to distinguish or discriminate against sterilized males. The classical case was in about 1940 on the island of Curaçao against Screw-worm (*Callitroga*) on goats: the male flies were sterilized by exposure to γ-rays, and dropped from planes at a rate of 400/square mile/week. The whole pest population was eradicated in 12 months. The life-cycle took only about four weeks to complete, and the females only mated once in their lifetime. Generally, autocide is most effective when applied to restricted populations (islands, etc.), but can be effective on parts of the continents. The Screw-worm eradication campaign was extended to the southern part of the USA where the pest is very harmful to cattle. In Texas 99.9% control was achieved in only three years. Male sterilization trials were effective against Mediterranean Fruit Fly (*Ceratitis capitata*) on part of the island of Hawaii in 1959 and 1960, but immigration from untreated parts of the island prevented control from being long-lived.

Chemosterilization has now advanced from a theoretical technique to a practical one, a variety of chemicals have been demonstrated to interrupt the reproductive cycles of a large number of insect species, see Curtis (1985).

Genetic manipulation

In reality this method is an extension of the previous one, in that the electromagnetic radiations (X-rays, γ-rays) induce *dominant lethal mutations* in the germ cells of the insects. These mutations in insect sperm have been used successfully in several eradication programmes. Lethal mutations are not lethal to the treated cell, they are lethal to its descendant in that the zygote fails to develop to maturity. These mutations arise as a result of chromosome breakages in the treated cells.

Potential uses for pheromones in pest control

Pheromones are reviewed in more detail in chapter 2 (page 11), but here they are considered in their actual roles in pest control.

The two obvious ways in which pheromones may be used in a pest control programme are firstly, in pest population surveys or for population monitoring (for emergence warnings, and spray warnings), and secondly for direct behavioural modification control. It is clear now from the work that has been done in recent years that pheromone traps are extremely useful in monitoring projects and this use is likely to be increased in the future. But to date there has not yet been a good example of pheromone use actually achieving a significant level of population control in a pest management programme; though, as already mentioned (page 13), there have been behaviour disruption trials on several different crops with very encouraging results.

Insect population monitoring. The presence or absence of a particular insect species in an area can be established through the use of attractant pheromones, so that control measures may then be exercised, if necessary, with precise timing. Previously field population monitoring relied largely on either light-trapping, which requires a source of electricity, or the finding of eggs on the crop plants. The finding of the first eggs on a particular crop is a very tedious and time-consuming process requiring a great deal of labour and is not particularly efficient. The examination of a few pheromone traps for the presence of male insects is relatively very easy, and much more efficient. Alternatively, the pheromone traps can be used to monitor the effectiveness of a pest control programme, even though not directly employed in the programme themselves.

Emergence of male Codling Moth in apple orchards in the spring in Europe and N. America, and Pea Moth, is now regularly monitored by the use of small paper (waterproof) pheromone traps with a sticky interior. Pink Bollworm, and other bollworms, on cotton crops in many parts of the tropics are likewise monitored with the use of these sticky pheromone traps, with considerable success. Various species of fruit flies (*Dacus* spp.) are monitored, sometimes using sticky pheromone traps and sometimes in traps with insecticides inside, in citrus and peach orchards to determine whether or not insecticide spraying is required, and if so just when. As more and more sex pheromones are being synthesized, and more chemical attractants are being

Fig. 4.10. Typical pheromone trap – the type used in fruit orchards.



discovered, it seems likely that the use of these chemicals in monitoring programmes will increase and will play a constant role in many pest management programmes.

Insect behavioural control. Bark beetles have been induced to fly to inappropriate host trees by aggregation pheromones; the host tree was either resistant and killed the boring beetles or they were unable to breed successfully. Carefully designed traps, incorporating the required visual stimuli, have been very successfully used in destroying bark beetle populations in forests in N. America.

Orientation to a trap baited with sex pheromones (*trapping-out*) has proved a feasible method of reducing populations of various moths and some fruit flies (Tephritidae). Destruction of males responding to a female sex pheromone-baited trap will, however, only effectively control a pest population if enough males respond and are destroyed to result in most females not being inseminated. Using theoretical population models it is suggested that such a trapping technique could be effective at low population densities, but would be unlikely to be effective at high densities. Such traps can kill the male insects either by adhesion (sticky traps) or by insecticides.

Male nocturnal moths have been observed to be additionally attracted to light in the presence of female pheromones. An experiment in America in 1966 using Cabbage Looper moths showed that when a cage of virgin females was placed on an ultra-violet (black-light) light trap the catch of males overnight was increased twenty-fold! With the recent synthesizing of Cabbage Looper sex pheromone this method of population reduction could be feasible agriculturally.

The *communication disruption technique* uses pheromones or sex attractants to prevent orientation of males to virgin females. This method could give direct population control of a pest species in a crop, but as yet no really convincing results have been obtained although some trials were fairly successful. The basic idea is to saturate the air with pheromone or sex attractant, or at least to make the concentration high enough so that the pheromone released by the wild females is imperceptible to the males; thus the males would not find the females in the crop and the females would not get inseminated. A recent experiment in the New World gave encouraging results. On cotton crops grown in southern USA, C. and S. America, Pink Bollworm is a major pest which builds up through six generations during the warmer part of the year, the last two or three generations generally being above the economic threshold for this crop and causing economic damage. A sex attractant, ‘Gossyplure’, was used in the communication disruption technique to saturate the air over the cotton fields with pheromone mimic so that the males would be disoriented by the odour and would fail to find and mate with many of the virgin females. This technique was timed to be used against the fourth and fifth Pink Bollworm generations. Following the use of ‘Gossyplure’, the level of cotton boll attack was significantly reduced, demonstrating that this technique can be agriculturally successful (Brooks, 1980). Similar experiments on other crops have given encouraging results.

It has been shown by experiments that most male moths show adaptation in their response to sex pheromones as it is weakened following previous recent exposure. In addition, it was shown that some non-pheromone chemicals may react on the antennal sense cells or central

nervous system to cause adaptation to the natural pheromone, but conclusive studies have not yet been carried out, although there would seem to be promise for eventual agricultural use.

Recent work by Cherrett and others have involved the addition of trail pheromones to baits for Leaf-cutting Ants in C. and S. America; this renders the bait pellets more attractive to the foraging ants which pick them up and take them back to the nest, making the poison bait more effective.

Pheromone release. The precise method of release of the pheromone, or mimic, is of importance, since for trapping purposes a steady, controlled release over a known period of time is most desirable. Some preparations are sold as impregnated rubber or polythene caps, or as a 'wick', each usually containing 1 mg of the chemical, which are generally effective for several (often four) weeks. However, experimentation has shown that there does appear to be a considerable difference in success of pheromone release, sometimes when a different matrix is used. This is a factor that requires consideration when experimentation or monitoring programmes are planned, rather like the importance of the base (matrix) of a bait in a baiting project.

A recent development described by Brooks (1980) is a hollow fibre formulation for pheromone release. Each tiny fibre is 1 ½ cm in length, sealed at one end, and with the lumen filled with pheromone which evaporates from the open end. In the experiment against Pink Bollworm two pheromone components were used in a 1 : 1 ratio and the release was steady over a period of 2–3 weeks.

Another method of delaying evaporation of the chemicals is by microencapsulation, but after some encouraging results ICI found that pheromones in gelatine capsules used in experiments in the Mediterranean region rapidly degraded in daylight because of the ultra-violet radiation. However, several successful uses of microencapsulated pheromones have now been reported (Matthews, 1979).

One of the companies now supplying a range of insect pheromones commercially for use in monitoring and control programmes is International Pheromones Ltd., with its main branches in the UK and Norway. Some of their products are for use in temperate situations and others are designed for use against tropical pests.

Chemical methods

Pesticides

Insecticides and their methods of application will be dealt with more fully in chapter 7. Only rarely does chemical application kill all the pests, and the few which survive usually soon give serious problems by the development of resistance. Chemical control is essentially repetitive in nature and has to be applied anew with each pest outbreak. However, this method is very quick in action and, for the majority of pest outbreaks, chemical control remains the method by which the surest and most predictable results are obtained. The different modes of action of insecticides are briefly listed below.

(a) Repellants – designed to keep the insects away; usually employed against mosquitoes and other medical pests.
(b) Antifeedants – certain chemicals block part of the feeding response in some phytophagous insects, and they can be used for plant protection.
(c) Fumigants – volatile substances that vaporize and the toxic gases kill pests within enclosed containers (food stores), greenhouses, or in soil.
(d) Smokes – finely divided insecticidal powders mixed with a combustible material; the insecticide is dispersed as 'smoke'; only of use in greenhouses and other enclosed spaces.
(e) Stomach poisons – have to be ingested to be toxic; either sprayed on to foliage (for foliage eaters) or mixed with a bait to encourage ingestion.
(f) Contact poisons – usually absorbed directly through the cuticle:
    (i) ephemeral – short-lived; usually a foliar application.
    (ii) residual – persistent (long-lived); soil or foliage application.
(g) Systemic poisons – watered into the soil, sprayed on to the plant, or applied to the trunk; absorbed and translocated by the plant and effective against sapsuckers especially. May be applied as sprays or granules, to either soil or foliage.

Pesticide application still remains the major weapon in the pest war, for obvious reasons, but we now find that often, sometimes usually, there are three definite post-application effects.

(a) Normal resurgence of treated pest – this always occurs as the target species initially suppressed by the insecticidal treatment shows a rapid population recovery after the decline of the treatment effect.
(b) Resurgence of the target species due to either development of a resistant biotype (as with the Brown Planthopper of Rice) and/or destruction of natural enemies.
(c) Outbreak of a secondary pest or pests, due to the alteration of the agroecosystem, usually by the destruction of natural enemies.

Insect resistance to pesticides

This topic is now of sufficient importance that a small section of text be devoted to it, for it is a major factor to be considered in many tropical and temperate pest management programmes.

In the 1940s the many new synthetic organic pesticides, mostly the organochlorine group, became widely available throughout the world for crop protection. Pesticides

such as DDT, BHC(HCH) and dieldrin were in many respects thought to be ideal for crop protection: they were highly toxic to insects (most groups), broad-spectrum and persistent. Control levels (kills) of major insect pests were consistently at the level of 98–99% or even higher. Many serious pests were controlled effectively for the first time, and a heavy dependence upon those pesticides resulted. Invariably, though, despite a high kill there was always a small proportion of individuals that possessed a natural resistance to such poisons, and of course during successive generations this genetically based, inherited, natural resistance spread throughout the insect (and mite) populations. After a number of years (generations) this resistance became manifestly obvious and a cause for concern. Eventually the entire local pest population became resistant to the chemical involved. These groups of individuals, with slight genetic differences from the main stock of the insect species, are known as *biotypes*. In disease-causing pathogens these races are known as *pathotypes*, and in a few cases a widespread pathogen is known to have as many as 20–30 pathotypes throughout its geographical range. Insects generally have far fewer biotypes, but the Brown Planthopper of Rice probably has a dozen biotypes in the area from India, through S.E. Asia, up to Japan. *Myzus persicae* occurs worldwide as a large series of biotypes, many of which show resistance to a large number of different pesticides.

Sometimes resistance to one chemical compound leads to resistance to other closely related compounds in the same group. For instance, after initial development of resistance to DDT, it rapidly developed to most of the other organochlorines. There followed resistance to the organophosphorous compounds, and now there is also resistance to some carbamates and some pyrethroids.

To date, more than 300 major pest species (insects and mites) have developed resistance to one or more major pesticides. An extreme case is that of Diamond-back Moth in Asia which shows very marked resistance to most of the pesticides used generally against caterpillars, with the exception of BTB; and it has now developed resistance to many of the new pyrethroids. One of the most spectacular cases of biotype development is that shown by the Brown Planthopper of Rice (*Nilaparvata lugens*) in India and S.E. Asia. Prior to the widespread use of diazinon on paddy rice it was only a very minor pest. Diazinon was the most widely used insecticide for general rice pest control in S.E. Asia for many years, and in 1970 this planthopper was first recorded as a major rice pest in a few localities; by 1975 it was recorded as a serious pest, and by 1980 was both serious and widespread. Recent work at IRRI has shown that the situation now is such that if diazinon is used on rice it invariably causes a resurgence of the planthopper.

It is generally thought that some 10–15 generations are required for the development of manifest resistance, and, as already mentioned, a widespread crop pest may show the development of several distinct biotypes over different parts of its distributional range. In temperate regions where many pests are uni- or bi-voltine, resistance develops slowly (6–10 years), but in the tropics, with the higher temperatures and no cold winter, insect breeding may be more or less continuous, and resistance may be strongly apparent after only 2–4 years in extreme cases. The Brown Planthopper of Rice can apparently develop a new biotype in 18 months on rice, that is about 18 generations.

To date, field resistance when encountered has been dealt with by just increasing the amount of pesticide applied, or using available chemical substitutes. The former remedy is generally useless (except for a very short time) and only adds to the general ecological disturbance as well as causing residue problems; it may also accelerate resistance development. Resistance problems are expanding and intensifying to such an extent that they are outstripping the development of new chemical pesticides.

One method attempting to cope with resistance problems is to use a mixture of two or more insecticides, and several fixed formulations are commercially available, very recently (2006) it was reported that in parts of India DDT was again being used against mosquitoes with considerable success as the insects were no longer resistant to this chemical.

Organic Farming. A recent development worldwide is the interest in organic farming and chemical-free produce. Many people are worried about the amount of harmful chemical contaminants that we eat daily as part of our overall diet, as well as water contaminants and air pollution. This was highlighted in the book by Rachel Carson (1964) - now half a century later there is a resurgence of interest in her book as her data and conclusions are just as valid now as they were then. Most of this interest is being shown in Europe and North America, but is spreading quite rapidly to many other parts of the world. The main feature of organic farming is the absence of pesticides (and some synthetic fertilizers) in the crop production. Quite a lot of the organic produce sold in Europe actually comes from the tropics, especially fruit, tea, coffee, and some vegetables. Most of the organic produce sold in supermarkets is more expensive to buy but many shoppers are willing to pay extra for the better quality.

In Britain the designation of "Organic Produce" is controlled by the Soil Association. Farms seeking this approval have to pass rigorous tests and there must have been no pesticide use for the previous two years.

Fairtrade. A major problem worldwide is the disparity between the payments made to the farmers for their produce and the final cost to the shoppers in the supermarkets. It appears that the supermarkets, which now dominate many aspects of crop production, are making a disproportionately large profit. Three obvious examples from the tropics are the smallholder production of tea, coffee and bananas. In an attempt to help the tropical smallholder farmers the *Fairtrade* organization was started in 1992 and now

it operates in 22 countries around the world. The Fairtrade Mark on produce guarantees five standards:-

- Giving the farmers a fair and stable price for their produce.
- Giving extra income for farmers and estate workers to improve their lives.
- Giving a greater respect for the environment.
- Giving small farmers a stronger position in world markets.
- Giving a closer link between producers and consumers.

For Fairtrade certification the farmers are not prohibited the use of pesticies but are required to use the minimum and judiciously so that residues are insignificant. This generally involves a careful pest management programme. There are several websites where further details are readily available about this movement that is proving ever more popular with consumers worldwide, such as:- http:/www.fairtrade.org.uk/pr 191102.htm

COOPERATIVES. for farmers and growers have long been established in most parts of the world through which the smallholders can buy seed, fertilizers and pesticides, and through which they can sell their produce.

GLOBALIZATION. Another recent trend worldwide has been the breaking down of national barriers economically - the countries (and people) which have available money are able to assume control of major businesses in other countries. For example in the UK major banks are now owned by Chinese as are motor manufacturers, the largest steel conglomerate is now owned by India, some railways by France and energy suppliers by Belgium, and so on.

In agriculture the major coffee and tea plantations in Africa and India have long been owned by Europeans, as were most plantation crops (sugarcane, rubber, bananas, etc.) in the tropics. But worldwide the bulk of the coffee, tea, cocoa, cotton crops are in fact smallholder grown, and nowadays farmer cooperative are being developed to expedite the sale of this produce. Previously vegetable and fruit crops as well as grain production had been for local consumption, but now excess grain is sold to neighbouring countries and fruit and vegetables are being flown worldwide to supply foreign supermarkets. In the British supermarkets are fruit from S. America, S. Africa, West Indies, Australia, and vegetables from Peru, Kenya, Malawi, etc. The supermarket phenomenon has now spread globally and are to be found everywhere including China, Sanawak, Trinidad; in the tropics the supermarket is usually incorporated into a vast air-conditioned shopping mall which acts as a social centre for the local community.

DIVERSIFICATION. Agriculture in the widest sense includes animal production aspects such as fishing, whaling, game hunting/production, fur trapping, etc. Because of dwindling stocks of wild game efforts are being made, often successfully, to rear the species under natural conditions, so that the wild stocks can be allowed to recover from their drastic over-exploitation.

Dairy farmers in the UK are seeking diversification as a means of final survival - some are now producing ice creams, cream and cheese, and still others are engaged in eco-tourism with holiday cottages. Some of the former whalers a running whale-watching trips and ecotours which are proving popular, as are tiger safaries in India. Kenya's major source of foreign income is from Safari holidays and tourism and several other African countries are doing the same.

Crop diversification has resulted in part from the development of new varieties and of the utilization of land for specific crops. Thus the highlands of Eastern Africa and SE Asia are being used for temperate vegetable and fruit production and this produce is being sold in Europe, out of season, with little or no local competition. The development of new varieties of crop plants has enables some tropical crops to be grown in temperate regions, and vice versa.

Most cases of resistance have been shown by the Arthropoda, but in recent years resistance has been also shown by rats, some fungi, and some weeds.

Antifeedants

Certain chemicals possess the properties of inhibiting the feeding of insect pests; these can be classed as antifeedants. The first chemicals noticed with these properties were initially referred to as repellents, but they are not repellents in that they do not merely drive the insect away to another plant but actually inhibit feeding on that plant. In laboratory tests insects have remained on treated plants indefinitely and eventually starved to death without eating the leaves. In field tests the insects were free to wander elsewhere seeking food; they either found weed plants to feed on or died of predation and starvation.

The most successful source of natural antifeedant is the Neem tree (Indian lilac, *Azadirachta indica*) and the closely related Persian lilac (*Melia azedarach*). Extracts from the Neem have long been known to have germicidal properties, but for the last ten years research in India and Germany has concentrated on its pesticide potential. Extracts from leaves and fruits (Neem oil) act as an antifeedant for many different insects (locusts, caterpillars and Hemiptera) and they also upset development and inhibit gravid females from oviposition. The active ingredient is a chemical called azadirachtin, and it is thought to be related to the ecdysonoids. The first Neem Conference was held in Germany in 1980 and was reported in *International Pest Control* (1981) No. 3, pp. 68–70 (25 references are listed).

The earliest antifeedant used in agriculture was ZIP (a complex compound zinc salt) used to keep rodents and deer from feeding on the bark and twigs of trees in the winter. The first recognized antifeedant for use in insect pest control was introduced by Cyanamid in 1959. Since then a number of compounds have been shown to possess antifeedant properties, but a commercially successful antifeedant has not yet been produced, although work is still progressing along this line, and it appears that Neem oil may be the first such product.

This line of research is being pursued in many different countries and it now appears that quite a number of plants

possess chemicals in their tissues that repel phytophagous insects and act as antifeedants. Another such plant is the sub-tropical shrub *Ajuga remota* (Labiateae) found in India. The active ingredient is called ajugarin (there are several) and is known to be particularly effective against African Armyworm. The ajugarins belong to the clerodanes which from part of the large group known as the terpenes (page 17). Ajugarin I (the main active component) has now been synthesized at Imperial College, London (1983).

Integrated control

The original concept of integrated control was developed to stress the need for understanding the complicated and antagonistic relationship between biological control and the use of chemical pesticides. Early pest control measures, up until about the turn of the century, were mainly concerned with the biology and the ecology of the pests, and in particular those aspects relating to their population numbers. Attempts were made to make the crop environment less favourable to the pests by a combination of cultural and biological methods. The chemical poisons available at that time were rather simple, such as kerosene, sulphur and some inorganic salts (lead, arsenic and mercury), and were not very effective as insecticides. The earliest attempts at biological control were in the early 1900s when various insect predators and parasites were imported into California and Hawaii to try to control some of the pests of the newly established *Citrus* industry. It was soon appreciated that the use of chemical poisons was basically inimical to biological control in that the poisons were not selective, and in fact the natural enemies were almost invariably more susceptible to poisons than the biologically very robust pests. In 1940 DDT was discovered to have insecticidal properties and was soon available commercially. It was capable of killing a broad range of insects and mites in small doses, and had a long-lasting residual activity. Literally almost overnight insect pest control was revolutionized, and a series of new synthetic organic insecticides was rapidly discovered and made available commercially. The organochlorine compounds (DDT, HCH, dieldrin, etc.) gave consistently high kills (98–99%) of a wide range of pests, as seed dressings, sprays and powders; persistence was lengthy and application was not difficult.

But there was no universal panacea after all; it soon transpired that pest problems often continued, and indeed sometimes worsened, and many undesirable side-effects were noted. These were the accidental destruction of natural enemies of the pests, and the development of resistance to the insecticides by the pests, and soon various other ecological disruptions became evident. Now, after considerable ecological damage and widespread resistance has developed, the culmination has been the extensive banning of the organochlorines in most parts of the World, particularly the total ban imposed by the Environmental Protection Agency (EPA) in the USA. The cycle of events is now completed as we are turning back to the original approach whereby biological and ecological understanding assumes predominance. The judicious use of the synthetic organic pesticides is a most important weapon in pest control, but must be used in conjunction with other appropriate methods.

The term *integrated control* was originally coined to describe the combining of biological control with compatible chemical application. (In this sense biological control included natural control and biological control *sensu stricta*.) The basic idea was to use chemical pesticides judiciously so as to avoid disrupting the existing natural control by killing the predators and parasites in the crop community. This can be done in several ways; by using specific, carefully screened pesticides only, by careful timing of the treatment, using minimal dosages, by reducing spray drift, and so on. This attitude developed because these two basic approaches to pest control are our primary resources, and as used in many instances in the past they have been in direct conflict with each other (Smith & van den Bosch, in Kilgore & Doutt, 1967).

Eventually accumulated experience and logic made it clear that it is necessary to integrate not only chemical and biological control, but all available techniques and procedures, into a single pattern aimed at profitable crop production together with minimal environmental disturbance. This realization led to the concept of *pest management* (PM) with its broad ecological approach to pest situations.

During the last decade the literature on pest control has been very confusing for in some instances integrated control was regarded in its original context and in many others it was virtually synonymous with pest management. After all, there is no basic qualitative difference between the two approaches, the difference is essentially quantitive. This confusion in terminology was widespread, but finally there appears to have been some international agreement to remove this confusion and the new term PM is now accepted as *integrated pest management* (IPM) as formulated by Glass (1975) on behalf of the Entomological Society of America. The term integrated control is regarded as an historical term, now superseded.

Some of the nicest examples of integrated control have come from tropical parts of the world, and include the control of Coffee Leaf Miners (*Leucoptera* spp.) in Africa and elsewhere, and the oil palm pest complex (bagworms and other defoliators) and cocoa pests in Sabah and Malaysia (Conway, 1972). It became apparent in these situations that the local natural control was of paramount importance and that the pesticides used formerly were killing the natural enemies of the pests and so chemical application was followed by extensive pest resurgence.

In temperate regions probably the best example of integrated control was that practised in glasshouses, where the red spider mites were controlled by predacious mites, the Glasshouse Whitefly controlled by parasitic wasps (Aphelinidae), and the aphids controlled with the aid of

nicotine smokes, or other judicious insecticide application. Nowadays the glasshouse pest control situation is even more complex in that aphids can be controlled using a fungus, and mealybugs using a predacious ladybird beetle.

The importance of biological control as a supplement to chemical use has long been appreciated in China, and they were in fact practising integrated control centuries before the term was coined (page 108).

A series of publications providing basic information on integrated control was produced by FAO in 1966 following a symposium on integrated control held in Rome in 1965: *Proceedings of the FAO Symposium on Integrated Pest Control*, Volume 1 (pp. 91), Volume 2 (pp. 186), Volume 3 (pp. 129).

Integrated pest management (IPM)
(formerly pest management (PM))

In 1967 the FAO panel of experts on integrated pest control defined *integrated control* as 'a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury'.

This definition incorporates the concept of pest management as defined by the Entomological Society of America, now expressed as IPM (Glass, 1975).

The concept of (I)PM is now well established. One of the earliest definitions was by Rabb & Guthrie (1970); they commented that originally integrated control generally referred to the modification of insecticidal control in order to protect and enhance the activities of beneficial insects (predators and parasites). Subsequently, however, integrated control interpretations have become more comprehensive until, now, some definitions of integrated control embody most of the essentials of pest management. Rabb preferred the term pest management because it connotes a broader ecological basis and a wider variety of opinions in devising solutions to pest problems.

Pest management can be defined as the reduction of pest problems by actions selected after the life-systems of the pests are understood and the ecological as well as economic consequences of these actions have been predicted, as accurately as possible, to be in the best interests of mankind. In developing a pest management programme, priority is given to understanding the role of intrinsic and extrinsic factors in causing seasonal and annual changes in pest populations. Such an understanding implies a conceptual model of the pests' life-system functioning as a part of the ecosystem involved. Ideally such a model would be mathematical, but a word or pictorial model may be useful in predicting effects of environmental manipulations.

Five of the most characteristic features of the population management approach to pest problems are as follows, after Rabb & Guthrie (1970).

(a) The *orientation* is to the entire pest population, or a relatively large portion of it, rather than to localized infestations. The population to be managed is not contiguous to an individual farm, county, state or country, but is more often international; hence a high degree of co-operation, both nationally and internationally, is a prerequisite for success.

(b) The *immediate objective* is to lower the population density of the pest so that the frequency of fluctuations, both spatially and temporally, above the economic threshold is reduced or eliminated.

(c) The *method*, or combination of methods, is chosen to supplement the effects of natural control agents where possible and is designed to give the maximum long-term reliability of protection, the minimum expenditure of effort and money, and the least objectionable effects on the ecosystem.

(d) The *significance* is that alleviation of the problem is general and long-term rather than localized and temporary, and that harmful side-effects are minimized or eliminated.

(e) The *philosophy* is to manage the pest population rather than attempt to eradicate it. The real significance of the concept is seen in relation to serious pest problems which defy solution through the more traditional approaches.

As previously stated, this broad ecological approach to pest control problems is still rather new in concept and, as yet, is more developed theoretically than in practice, particularly with regard to the use of computer models.

There is now quite an extensive list of publications concerned with IPM on a worldwide basis, many edited by the pioneers in this field, such as Apple & Smith (1976), Rabb & Guthrie (1970), Metcalf & Luckmann (1975), Watson, Moore & Ware (1975). In some of these books are published specific IPM programmes for a range of particular crops. Other IPM programmes for specific crops have been published by Rabb, Todd & Ellis (1976) for tobacco in N. Carolina, Hensley (1980) for sugarcane in Louisiana and Chu (1980) for sugarcane in Taiwan. Many such papers are being published regularly in *Ann. Rev. Entomol.* as can been seen from the Bibliography. A series of papers dealing with IPM for major crops has been produced by the FAO as Plant Production and Protection Papers: *Guidelines for integrated control of rice insect pests* No. 14, pp. 115 (1979); *maize pests* No. 18, pp. 91 (1979); *sorghum pests* No. 19, pp. 159 (1979).

A recent publication of interest called *Integrated Pest Management* was written for the US Council on Environmental Quality by Bottrell (1979), and it views the subject in its broadest aspects.

Clearly some of these programmes are in the category of first attempts, and as yet rather crude, whereas others are quite elaborate, very sophisticated and obviously very effective. Presumably, the basic problems with a particular crop remain much the same wherever the crop is grown, but the

pest and disease spectra will be different in each locality where the crop is important (i.e. site-specific). The ultimate aim for crop protectionists is clearly an IPM programme for all the more important crops in all the major agricultural regions of the world.

Results of recently implemented IPM programmes in Canada, USA, and Europe have shown a pesticide usage reduction of 35–80%; a general overall reduction of 50% appears possible for many crops.

A recent trend in the literature is to refer to IPM meaning 'insect pest management', but the precise meaning is the same as the original use of 'integrated pest management.'

Eradication

In most cases, pest control is undertaken to reduce the population density of an insect to a point at which the damage done is not of economic significance; very rarely is complete eradication the goal, and even more seldom is it achieved. The more usual cases of complete eradication are directed against pests of medical importance, and very successful campaigns have been carried out in many areas against diseases such as malaria, yellow fever and dengue. Against agricultural pests about the only time eradication is aimed at is when a new pest, which is potentially very serious, has been introduced into a country and has not spread too far. The campaign is often very costly and difficult but can be won if the pest is still restricted to a relatively small area.

Some eradication programmes have been successful against Screw-worm (*Callitroga*) and fruit flies (*Drosophila* spp.), when sterile-male techniques were employed. This technique is particularly suitable for eradication programmes, especially in restricted locations.

California and Florida in the USA have multimillion dollar *Citrus* industries, as well as for peach, fig, guava and many other tropical and sub-tropical fruits. Some very damaging fruit flies are still not established here, as are some other pests such as San José Scale and California Red Scale (Florida). Some years ago Medfly (*Ceratitis capitata*) was accidentally introduced into Florida; a total of 0.7 million hectares of *Citrus* orchards and adjoining land was sprayed with insecticides, at a total cost of US $8 million; but the project was successful and the Medfly population exterminated. The total value of the Florida fruit industry was at that time about $180 million. Very recently (1981) Medfly was accidentally established in California and presented the Governor with a difficult decision. With a $14000 million fruit industry in California at stake it was imperative that an aerial spraying eradication programme be started quickly, but in recent years the environmentalists in California have become a very powerful political lobby and they objected strongly to the idea of aerial spraying of suburban homes and gardens. The Medfly, was, however, too serious a threat so the eradication project went ahead.

Colorado Beetle is accidentally introduced into the UK in most years, but this very damaging pest of potatoes is usually destroyed quite rapidly. Since the 1933 Colorado Beetle Order all farmers and growers are aware of this pest and the danger it presents, and the odd infestation is usually reported promptly. On receipt of a report, the Ministry of Agriculture regional staff take immediate action to collect and kill adults and larvae on the potato foliage, and also to fumigate the soil in the infested area in order to kill any pupae that might be present.

Several forestry pests in North America have been the subjects of eradication programmes because of the tremendous damage potential they represented in both the deciduous and coniferous forests; these include Gypsy Moth, Winter Moth, Larch and Pine Sawflies; the list is quite long! Some of these pests were eradicated in some regions following extensive aerial insecticide spraying; others succumbed to introduced parasites (page 106), but others, although some measure of control was achieved, still remain a problem.

The decision to eradicate a pest is a grave biological responsibility and should not be made unless careful study, involving diverse perspectives, has produced convincing evidence that the benefits to be accrued more than balance the ecological impoverishment represented by removing the pest species.

The present state of insect pest management

In Europe and N. America there has been extensive publicity given to recent record harvests, and general agricultural over-production has led to the so-called 'grain mountains', and other produce surpluses, that are embarrassing the EEC administrators. This recent high level of production is due partly to the advanced level of agriculture being practised, particularly large-scale mechanization and the abundance of agrochemicals. This publicity leads to a general assumption that in temperate countries crop pest problems are greatly diminished now, and the main pest problems are only to be found in the tropics.

But in a recent article by Pimental (1985) he points out that these record harvests are misleading in that in the USA (probably the heaviest user of insecticides in the world) during the last 35 years there has been a ten-fold increase in insecticide use, and over this period crop losses have actually doubled (7% to 13%).

Integrated pest management (IPM) for insects has now been studied and discussed for more than 20 years, but up to the present time there has still been more discussion than action in regard to its implementation. One major problem has been the lack of a truly interdisciplinary approach to the basic research. Another has been the reluctance of farmers to appreciate and accept the principles of IPM and thus to adopt

this long-term approach to control: they usually still prefer frequent and repeated applications of insecticides.

Enough IPM programmes have been carried out in N. America and Europe to demonstrate the effectiveness of this approach, and if an overall reduction in insecticide usage of 50% can be achieved the future for IPM is surely bright. It is now totally accepted in scientific circles that the IPM approach is without doubt to be aimed at, but it does require a great deal of basic knowledge of the biology and ecology of both crop and pest and this is not often readily available yet. So at the pesent time it is desirable to adopt the BEST PRACTICE approach and to do the best that is possible using the existing knowledge. Of course in the hope that in the future more knowledge will be available to permit a complete IPM approach.

5 *Pest damage to crop plants*

The agricultural entomologist has a distinct advantage over his colleagues in nematology and plant pathology in that the damaging organisms with which he is concerned are relatively large and usually to be found in the vicinity of the damage on the crop plant. This helps to make the identification of insect pests a relatively simple matter, at least to the level of family and genus.

For many control purposes pest identification to family, or preferably genus, is often adequate, for most members of most insect (and mite) families produce the same type of damage on the crop plant and are likewise controlled by the same practices. After all, this is to be expected, since the object of insect systematics is to place closely related species together in the same taxa. However, there are occasions when the specific identity of the pest is important, especially in the case of aphids and other Homoptera that are virus vectors. For example, *Toxoptera citricidus* is the vector of Citrus Die-back disease (Tristeza) in Africa and S. America, whereas the partially sympatric and morphologically very similar *T. aurantii* is apparently not a vector. The genus *Ceutorhynchus* is an example where several closely related species have quite different biologies. At such times a high level of taxonomic expertise is demanded, but these occasions are relatively few. Generally however, it is necessary to identify the pest correctly (to the appropriate systematic level) in order that the economic significance of the infestation be accurately assessed, and the most appropriate control measures be applied.

On occasions only the damaged plant may be found, or else there may be several similar pests on the crop and it may not be evident which insects are responsible for which damage. Some pests are nocturnal or crepuscular in habits and during daylight hours remain hidden in the plant foliage or the soil, others drop off the plant and hide in the soil litter when anyone approaches. The damage inflicted on the various parts of the plant body is, however, sometimes characteristic of a specific pest, or a group of closely related pests. Then the experienced entomologist will usually be able to make a fairly accurate determination (identification) of the identity of the damaging animal.

In practice the situation is often more complicated. Several quite unrelated insect groups produce almost identical attack symptoms on the plants; for example, leaf miners may be the larvae of Diptera (Anthomyiidae, Ephydridae, Agromyzidae) or Lepidoptera (Gracillariidae, Phyllocnistidae, Nepticulidae, Tischeriidae, Lyonetidae) or Coleoptera (Chrysomelidae, Hispinae, Halticinae). 'Dead-hearts' in graminaceous seedlings may be produced by larvae of Lepidoptera (Pyralidae, Noctuidae) or Diptera (Muscidae, Anthomyiidae) or Coleoptera (Scarabaeidae). The more generalized defoliation resulting from the browsing and grazing of herbivores can be very difficult to identify without extensive practice, and even then it is often not possible. Leaf-eating is the normal method of feeding of some mammals (ungulates, pigs, rabbits, rodents), birds (sparrows, ducks, etc.), molluscs (slugs, snails), most grasshoppers, locusts, caterpillars, and some beetles (both larvae and adults). If one is presented with such damaged plant material in the laboratory or regional 'Plant Clinic', then identification of the causal organism may be quite impossible. But if the plants are examined *in situ* in the field various clues such as footprints, scats, hair, feathers, slime trails, etc. may permit the entomological detective to identify the culprit. Detailed ecological knowledge is of great assistance in such cases, especially knowledge of local animal migrations and behaviour.

The situation is actually even more complicated in reality because damage similar to that produced by some pests may also result from adverse weather conditions, such as drought, flooding or waterlogging of the soil, lightning-strike, hail, frost, sun-scorch and strong wind. Excessive fertilizer application, herbicide damage and use of insecticide on susceptible crops also produce distortions and damage to the plant body. Disease organisms (bacteria, fungi, viruses) and nematodes (eelworms) produce some symptoms reminiscent of insect and mite attack, and mineral deficiencies (manganese, magnesium, etc.) result in symptoms similar to various virus infections.

The growing crop will be subjected to the vagaries of the weather, prevailing soil conditions, and the ravages of maybe a vast pest and disease complex, which altogether will influence the basic genetic control of the development of the plant body. All of these constituent ecological factors will be interacting, and the various agricultural advisers (agronomist, horticulturalist, pathologist, entomologist) will be confronted by the end-result of this complicated interaction. Obviously, in some situations the adviser cannot hope to rectify the situation, but only aim at minimizing damage in an attempt to secure a crop yield of economic proportions.

It should finally be noted that various pests and disease organisms interact by *predisposition*, so that an infected plant may be more susceptible to pest attack, and a slight infestation may produce unusually severe symptoms. This also applies to climatic and edaphic factors; a water-stressed plant is invariably more susceptible to pest attack.

Pest damage assessment and crop yields

The ultimate aim of agriculture is to produce a sustained economic yield of crop produce, so it becomes of prime importance to understand the effect of the insect pest population on the subsequent yield or harvest. Obviously, if the pests are causing no crop loss their presence on the plants and the damage they cause may be ignored, and in the context of ecological stability they should be left alone! However, most pest populations produce some damage of significance, but the damage assessment in relation to possible or expected yield loss is difficult. The total number of

interacting factors responsible for determining crop yield is quite overwhelming, and any decision as to the probable effect of any single factor, such as the population of one insect pest species, is problematical. However, the gradual accumulation of empirical data over many years has resulted in our being able to make various generalizations about some pest populations and their probable effect on crop yield. These results are used to define economic injury levels (and economic thresholds) for some pests on some crops in different parts of the World. But in general, many more data are required for many more pests on the more important crops, especially those in the tropics.

Part of plant body damaged

Some types of damage are obviously more important than others, depending upon the part of the plant body damaged and the part harvested; if the two are the same then clearly the damage is more serious. A single Codling Moth larva can effectively destroy a single apple or peach, and a relatively small number can ruin an entire crop. On the other hand an apple tree can accommodate a large number of foliage-eating caterpillars, sap-sucking bugs, and root-eating beetle larvae, with no discernible loss of yield. In general, root crops can stand considerable leaf damage without appreciable yield loss; pulses and most cereals can likewise tolerate leaf-eating, root-eating and sap-sucking (with a few exceptions) at a moderate level. Vegetables such as cabbage, lettuce, celery, etc., may have their outside leaves removed at harvest, prior to sale, so damage to the outer leaves is relatively unimportant.

It has long been known that many crop plants can tolerate partial defoliation without discernible loss of yield; two well-documented cases are cucumbers attacked by Red Spider Mite, where 30% of leaf cover has to be damaged before there is an effect on yield, and sugarbeet, where young crops suffer little loss of yield unless defoliation exceeds about 50%.

In summary, damage which can be ignored on one crop may be of considerable economic importance on another (even closely related) crop, so damage assessment is different for each crop grown. For example fig. 15 shows

Fig. 15. A. Examples of five closely related crops (*Brassica* spp.) which have different parts of the plant body harvested, and also a generalized seedling.

1. *Brassica* seedling
2. Broccoli (*B. oleracea* var. *botrytis*), grown for flower heads
3. Brussels sprouts (*B. oleracea* var. *gemmifera*), grown for lateral buds
4. Cabbage (*B. oleracea* var. *capitata*), grown for ‘heart’, i.e. telescoped main shoot
5. Turnip (*B. rapa*), grown for swollen root
6. Rape (*B. napus*), grown for seeds as a source of oil

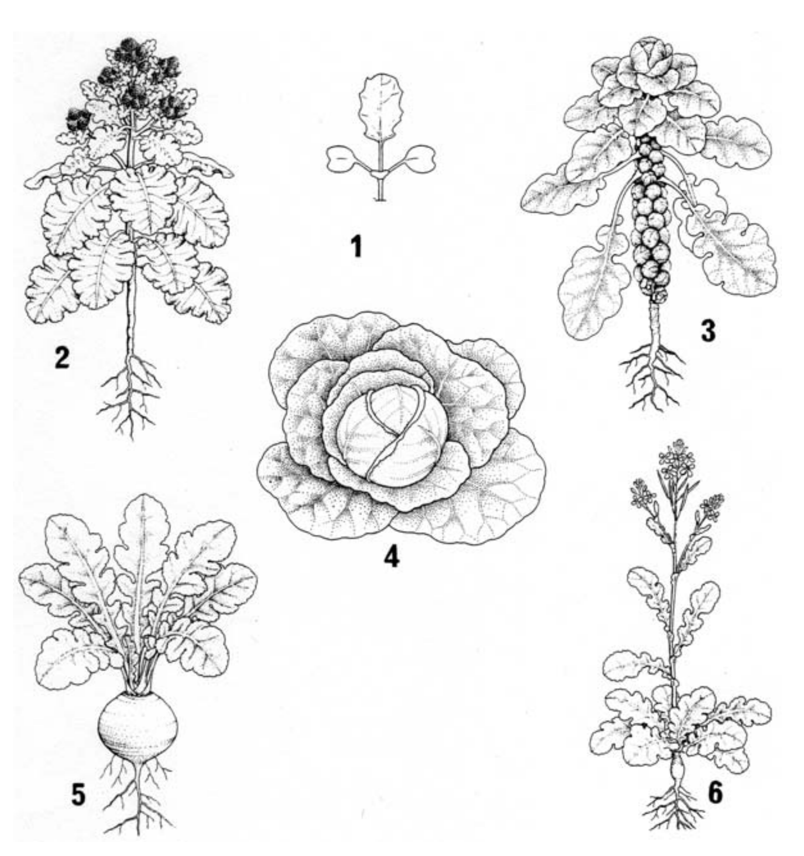
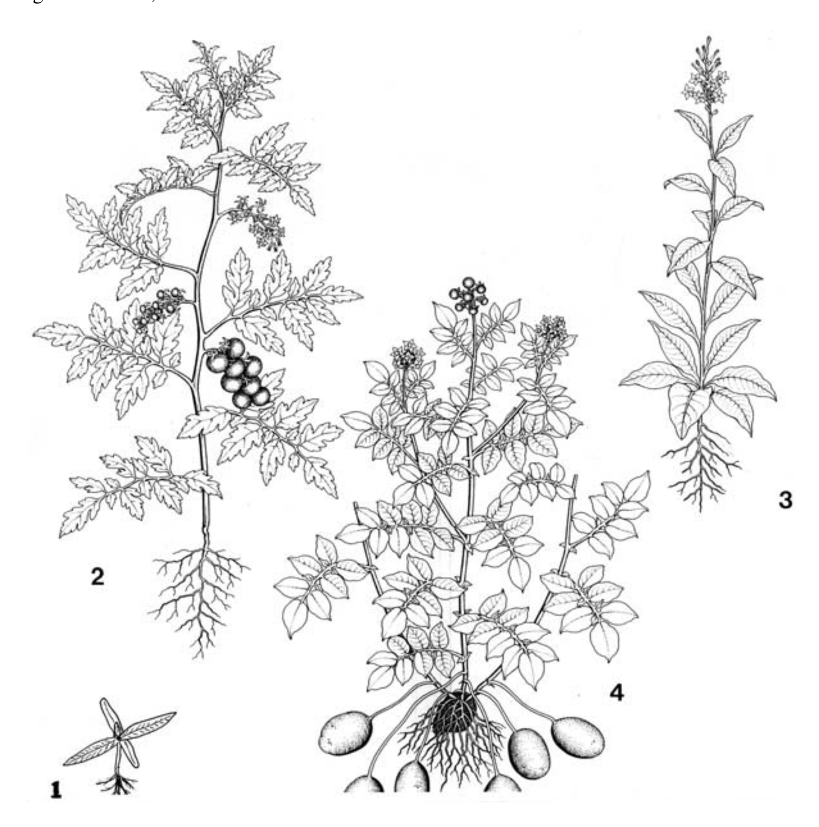


Fig. 15. B. Similarly four species of cultivated Solanaceae.
1. General *Solanum* seedling
2. Tomato grown for the fruit
3. Tobacco grown for the leaves, and sometimes for seed
4. Potato grown for underground tubers, and sometimes for seeds



five different *Brassica* crops together with a seedling; should the seedling be killed by Cabbage Root Fly, cutworm, or white grub, then the damage is usually serious for the entire future plant is lost and there is a large gap left in the field which encourages weed development (except rape). With Broccoli the flower heads are eaten, so damage to lower leaves, and some root damage can be ignored. Brussels sprouts are lateral buds harvested over the winter period, so late caterpillar defoliation in the autumn may be of no consequence, but a single Cabbage Root Fly inside a button for freezing is serious damage. The many types of Cabbage are grown for the 'heart', so all the outer leaves may be damaged without affecting the saleability of the heart. Turnip is one of the cruciferous root crops and will tolerate considerable leaf damage, but even slight Cabbage Root Fly damage may spoil the appearance of the root. Rape is becoming more and more important in many regions as a source of seed for oil extraction, and in this crop it is the flower and pod pests that are important (as they are also for the other crops grown to seed); small numbers of plants destroyed have no effect on final yield because of the density of the crop.

Details of sale procedure may be relevant; sprouts grown for freezing have to be totally free of Cabbage Root Fly maggots; turnips sold with soil adhering to the root can have surface tunnelling by Root Fly maggots, but, if washed and prepacked in plastic, maggot tunnelling may affect sale (now some retailers are trimming off the roots prior to sale, and also removing surface tunnels). There will always be some unusual cases causing problems. Some cabbages are unsaleable not because of the caterpillar damage but because of the extensive frass accumulation between the leaves. Broccoli heads have also been unsaleable when infested with Diamond-back Moth pupae inside their flimsy silken cocoons, although there was no actual damage.

Compensatory growth

Most plants produce far more leaf cover than actually required, and of course grazing by herbivores is to be

expected; the plant responds to grazing by compensatory growth, either in the form of extra leaves, or in Gramineae by tillering if the apical shoot is killed. The *leaf area index* (l.a.i.) of many crop plants may be as high as 3, 4, or 5, so that much of the lower foliage is shaded by the upper leaves, and with closely spaced crops the lower parts of the plant will be shaded by adjacent plants.

Some plants produce far more flowers and fruits than the plant can actually sustain, and there is a regular natural flower-fall and fruit-fall. In temperate crops one of the most noticeable cases is with apple, where there is a flower-fall followed by an early fruit-fall and sometimes a later fruit-fall. With a number of crops there is a tendency towards overproduction and the loss of later flowers or buds may be beneficial (e.g. by Pea Midge), leading to a smaller yield of better fruits and more simultaneous ripening which makes harvesting easier. It must be remembered that in all terrestrial ecosystems the Spermatophyta, and in fact all members of the Plant Kingdom, are the main primary producers and so heavy grazing of all crop plants is to be expected. It will be equally expected that the plants have evolved various methods of counteraction.

With some crops the inter-row spacing and the intra-row spacing habitually employed is often a compromise between yield per plant, overall yield, canopy density (to reduce weed competition) and other factors. If a row of crop plants is destroyed by pests then the adjacent plants usually would grow larger and bear more/larger fruit so that the overall crop yield does not necessarily diminish.

Beneficial effects of pests

One anomalous aspect of pest infestations is that sometimes the overall effect is agriculturally beneficial; occasionally the yield is actually increased, sometimes it is 'quality', and sometimes the effect is more subtle. The most usual effect is one of 'pruning' whereby suppression of growth of one part of the plant body results in the increase in size of another part, usually the 'fruits' or harvested storage organ. Some cereal crops after early shoot fly attack may show an increased yield at harvest because of increased tillering in response to pest damage. Defoliation of some crops of potato and turnip has resulted in small yield increases, though the precise way in which this came about is not clear. Some legumes after pest attack produce fewer seeds but larger ones, and this could be regarded as an increase in quality. Small infestations of *Aphis fabae* may increase yields of field beans because of their suppressing effect on apical growth. Similarly Pea Midge can increase the marketable yield of peas for freezing by effectively destroying the apical shoot (causing a 'nettle-head') and encouraging simultaneous ripening of the peas in the pods already formed. (For the UK freezer-market a pea plant with four simultaneously ripe trusses is aimed at.) Potato tubers of very large size are difficult to market, and it has been noticed that infestations of *Aphis nasturtii* have decreased the size but not the number of tubers, so although total yield weight might be reduced the actual value of the crop at market could be increased. And as already mentioned, sometimes a pest attack destroys young plants which are closely spaced, and adjacent plants take advantage of this reduced competition pressure for space by increasing in size and yield, and occasionally an overall yield increase has been recorded.

Repelling of insect pests

Some plant species and some varieties of crop plants possess properties, either physical or biochemical, that deter insects from either feeding on their tissues or from ovipositing. These topics have been included in the section on plant resistance to pests, and in chapter 4 on page 47.

Pest infestations

There are two basic ways in which pest infestation (or damage) can be assessed. The *incidence* of the pest (or damage symptoms) is generally the proportion of plants in a sample which are host to the pest (or which show damage symptoms), and is usually expressed as a percentage. The *severity* of the infestation is a measure of the size of the pest population on the plants, or the extent of the damage done, and is often measured as so many insects per plant, per bush, per 10 leaves, egg masses per plant, etc. And of course the total damage caused to a crop is a combination of severity of infestation together with *duration* (time).

In ecological studies of populations of both plants and animals, several methods of assessment are employed. These are based upon the proportion of area covered within the habitat (for plants), or the number of animals seen or sampled, in relation to area, or proportion of plants examined (sampled). Botanists are able to use more precise systems for plant population assessment because of the immobility of the organisms, and the three most widely used methods employ between 4 (Raunkiaer, 1934), 6 (Braun-Blanquet, 1927) and 11 (Domin) abundance categories. But for small, highly mobile insects the latter level of precision is not feasible, especially when different recorders are being used. In the UK the *Biological sites recording scheme* advocates the use of four abundance/frequency categories for population size assessment, without the use of lengthy or detailed sampling procedures, and this approach would seem to be appropriate for assessing field populations of insect pests on crops. These categories of abundance are as follows:.

abundant	(a) =	very common	(VC)
frequent	(f) =	common	(C)
occasional	(o) =	uncommon	(U)
rare	(r) =	rare	(R)

The alternative categories in the right-hand column would appear preferable as their designation is somewhat more obvious. Further details on pest population assessment can be found in the publications by Southwood (1978), Bardner & Fletcher (1974), and FAO/CAB (1981).

Damage assessment

It was suggested by Bardner & Fletcher (1974) that the term *injury* be used for slight (i.e. non-damaging) effects of insects feeding or other activities on the growth or appearance of crop plants; and that *damage* is injury resulting in a measurable loss of yield or reduction in quality. This distinction would be most useful, but to date in the literature these two terms are used more or less synonymously, and of course the term 'economic injury level' is well established.

The extent of crop damage is usually proportional to the numbers of insects present, and would accordingly be rated as follows:

very severe	(VS)	= 1 or	1
			2
severe	(S)	= 2	3
mild	(M)	= 3	4
very mild	(VM)	= 4	5
			6

In some systems of recording a numerical categorization is used, and a six-point scale seems to be quite popular; presumably in this case number 6 (and 'very mild') come under the 'injury' category of Bardner & Fletcher (1974) and would be detectable but not of any economic importance. With simple damage, such as leaf lamina being eaten or apples infested with Codling Moth larvae, damage can be expressed easily as proportion of lamina destroyed or percentage of fruits infested per tree. In some systems numbers of pests present are correlated empirically against expected loss of yield (percentage), on a scale of no loss (0%) to total loss (100%).

Because each crop has its own growth characteristics (see below), and the vast diversity of types of pests and pest damage and all the other factors involved with crop production, it is not possible to generalize extensively. Damage assessment will remain different for each crop and sometimes also for each major locality as the pest complex usually varies regionally. It is however generally agreed that for most purposes a damage assessment scale of not more than six levels is preferable, for easy recognition in the field by non-experts, and it is recommended that a large number of small (easily categorizable) samples be taken rather than a small number of large samples; this also caters better for the uneven pest distribution within the crop, which is usual.

Plant age/stage of development

This could alternatively be termed *crop vulnerability*. Casual inspection of pest infestations can be very misleading in relation to actual damage done. Pests such as aphids may at times be very damaging, but at other times a heavy infestation may be very conspicuous and unsightly (especially if associated with sooty moulds) whereas the actual damage might be slight.

Many crops are only vulnerable to certain pests at a particular time in their growth (development). Generally the two most stressful times for plants are the time of establishment and the time of flowering/fruit development, and at these vulnerable times pest damage is often most serious. Cereals are only susceptible to Shoot Fly attack when very young; by the third or fourth leaf stage they are no longer attacked. Bean Fly only kills seedlings of *Phaseolus*, on larger (older) plants the infestation occurs in the leaf petioles where they have little effect on crop yield.

There have long been established well-defined growth stages for most of the major crops as a necessity for convenience in cultivation practices. Fig. 16 shows the growth stages for wheat (and other temperate cereals), and for comparison fig. 17 shows the growth stages for rape and fig. 18 for sugar beet; all are taken from FAO/CAB (1971).

With wheat, and other cereals, aphid infestation is most damaging at the young seedling stage (at establishment) and later on the flag leaf and head at the start of flowering; the flag leaf is mainly responsible for the photosynthetic activity providing foodstuff for grain formation. With autumn sowing of many cereals now widely practised in the UK, the plants are long past the susceptible stage (to aphids) by the time the aphids become abundant in the spring and early summer. Similarly, field beans sown in the autumn are generally not at risk from *Aphis fabae* in the spring, as the vulnerable stage has passed.

Most annual crops are grown directly from sown seed in the field, sometimes precision-drilled (e.g. sugarbeet), sometimes furrow-drilled and requiring thinning (now mostly superseded by precision-drilling), and sometimes furrow-drilled quite densely (cereals and rape), and sometimes grown in rather dense beds (some carrots, some onions). With all these crops the tiny seedlings are exposed in the field to all the local pests. Some crops, such as many brassicas, tobacco, etc., are first grown in seed-beds and then transplanted into the field. In the seedbeds the plants may be intensively protected, but at the time of transplanting and subsequent establishment the seedlings are very vulnerable.

Pest thresholds

The need to establish international co-operation for studies on crop damage assessment, and for publication of data, to enable pest control measures to be applied on a more rational basis led to the FAO (Rome) convening a *Symposium on crop losses* in October 1967, which was attended by representatives from 36 countries. One recommendation was to prepare a manual of methodology; this was published for FAO by CAB in 1971, with supplement No. 1 in 1973, No. 2 in 1977, and No. 3 in 1981. The *Manual* includes loss-assessment methods for a total of about 80 pests on 27 crops, about half of which are tropical and half temperate. The assessment techniques here presented are extremely varied, both direct and indirect; in some cases infestation levels/yield losses are clearly evident and simply expressed, in others regression analysis of sampling data is required.

Fig. 16. Growth stages in wheat, oats, barley and rye (modified from drawings by E.C. Large, 1954).

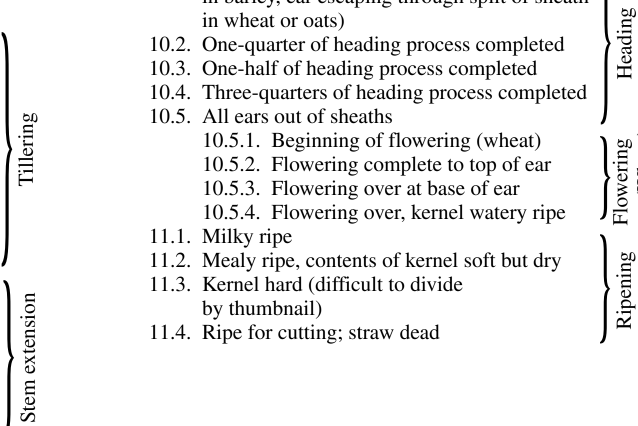
Stage 0 Pre-emergence

Tillering:

1 One sprout (number of leaves can be added) = 'grairding'
2 Beginning of tillering
3 Tillers formed, leaves often twisted spirally; in some varieties of winter wheats, plants may be 'creeping' or prostrate
4 Beginning of the erection of the pseudostem, leaf sheaths beginning to lengthen
5 Pseudostem (formed by sheaths of leaves) strongly erected

Stem extension:

6 First node of stem visible at base of shoot
7 Second node of stem formed, next-to-last leaf visible
8 Last leaf visible, but still rolled up, ear beginning to swell
9 Ligule of last leaf just visible
10. Sheath of last leaf completely grown out, ear swollen but not yet visible



Heading:

10.1. First ears just visible (awns just showing in barley, ear escaping through split of sheath in wheat or oats)
10.2. One-quarter of heading process completed
10.3. One-half of heading process completed
10.4. Three-quarters of heading process completed
10.5. All ears out of sheaths

Flowering (Wheat):

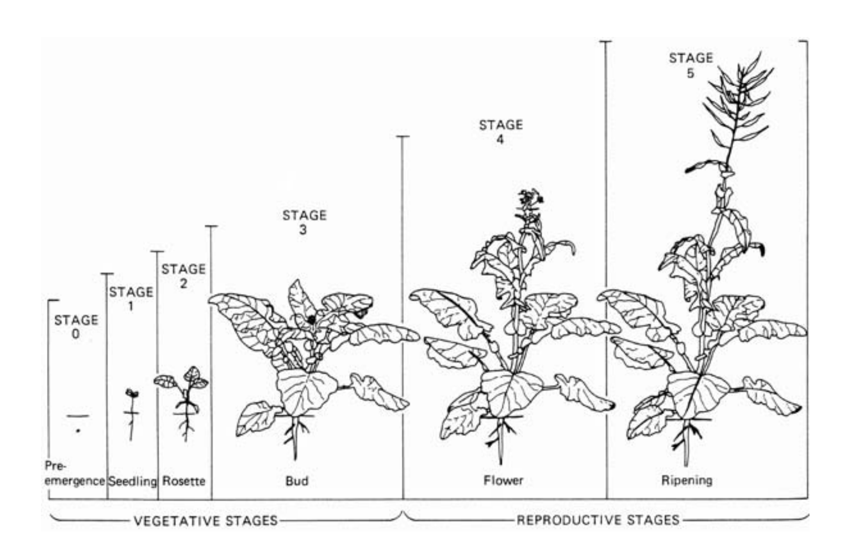
10.5.1. Beginning of flowering (wheat)
10.5.2. Flowering complete to top of ear
10.5.3. Flowering over at base of ear
10.5.4. Flowering over, kernel watery ripe

Ripening:

11.1. Milky ripe
11.2. Mealy ripe, contents of kernel soft but dry
11.3. Kernel hard (difficult to divide by thumbnail)
11.4. Ripe for cutting; straw dead

Fig. 17. Growth stages in rape (modified from Berkenkamp, 1973, and Harper, 1973). Descriptions are based on the main stem

Stage 0 Pre-emergence
1 Seedling
2 Rosette
2.1. First true leaf expanded
2.2. Second true leaf expanded (add 0.1 for each additional leaf)
3 Bud
3.1. Inflorescence visible at centre of rosette
3.2. Inflorescence raised above level of rosette
3.3. Lower buds yellowing
4 Flower
4.1. First flower open
4.2. Many flowers opened, lower pods elongating
4.3. Lower pods starting to fill
4.4. Flowering complete, seeds enlarging in lower pods
5 Ripening
5.1. Seeds in lower pods full size, translucent
5.2. Seeds in lower pods green
5.3. Seeds in lower pods green-brown mottled
5.4. Seeds in lower pods brown
5.5. Seeds in all pods brown, plant senescent



In addition to the 40-odd temperate examples included in the *Manual* there are threshold recommendations locally available in most countries; a few of the more useful examples available in the UK, through local ADAS (MAFF) offices, are listed below.

Some insect pest thresholds for crops in the UK (ADAS, MAFF).

(1) Wheat
– Cereal Grain Aphid (*Sitobion avenae*): five aphids per ear at the start of flowering, with weather conditions fine and settled.
– Rose–grain Aphid (*Metopolophium dirhodum*): 30+ aphids per flag leaf.

(2) Rape
– Blossom beetles (*Meligethes* spp.): 15–20 adult beetles per plant, at flower-bud stage.
– Cabbage Seed Weevil (*Ceutorhynchus assimilis*): one or more weevils per plant at flowering (spray at end of flowering).

(3) Potato (ware crops)
– Aphids: average 3–5 aphids per true leaf, in a sample of 30 each of top, middle, and lower leaves taken across the field. (On retarded crops two aphids per leaf may be appropriate).

(4) Pea
– Pea Moth: 10+ moths per pheromone trap on two consecutive twoday periods (wait 3–4 days then apply sprays).
– Pea Aphid (*Acyrthosiphon pisum*): 5–10% of the growing tips infested.

(5) Field bean
– Black Bean Aphid (*Aphis fabae*): if 5% or more of the plants on S.W. headland are infested (spring-sown crops only; winter-sown crops are not at risk).

Fig. 18. Growth stages of the sugar beet root crop (after G.D. Heathcote on behalf of IIRB).

(6) Fruit trees – Fruit Tree Red Spider Mite (*Panonychus ulmi*): when more than seven leaves in a 50-leaf sample carry more than four mites per leaf.

(7) Apple – Winter Moth (*Operophtera brumata*): larvae on 10% of trusses at bud-burst.
– Apple–grass Aphid (*Rhopalosiphum insertum*): aphids on 50% of trusses at bud-burst.
– Rosy Apple Aphid (*Dysaphis plantaginea*): any aphids present on trusses at bud-burst.

It has been shown for some crops that the effect of a particular pest infestation level will vary according to the usual yield of the crop, a high-yielding variety of crop suffering relatively less reduction in yield than a lowyielding variety. Crops such as pulses, sorghum and some other cereals, where varietal differences reflect in large differences in expected yield, should for assessment purposes be distinguished as high, medium, or lowyielding varieties. This tends to be more of a problem in some tropical countries rather than in most temperate ones, as crop yields there are more often at the 'primitive' level (page 29).

Crop loss profile

One of the first objects in an IPM programme is to establish a *crop loss profile* for the crop in question; this defines the *pest complex* and in particular the *key pests* which are in the main responsible for yield reduction in that crop. When the main sources of crop loss are identified it is necessary to describe and quantify the pests. The assembling of these data has been called the *preliminary portfolio* (Large, 1966). Such assemblage has been done for some temperate crops, such as cereals, but to date mostly for the disease complex rather than the animal pests. After the compilation of the preliminary portfolio a *damage function* can be designed; this is an equation relating the level of pest infestation to yield loss, usually expressed as a percentage. Damage functions are now in use for many crops worldwide, but mostly in relation to diseases and nematodes rather than insect and mite pests. A major problem in designing damage functions is that loss is calculated (estimated) in relation to a *reference expected yield*, but the derivation of this reference expected yield for most crops is problematical at best. The information on crop losses is usually acquired through national and international surveys (e.g. FAO yearbook) and other sources of indirect data, and the reliability of such data are really highly suspect at times.

Types of pest damage to crop plants

In order to break down this section for convenient handling it is necessary to subdivide according to the part of the plant body being attacked by the pest. In practice this is not too satisfactory because of overlap; for example a shoot consists basically of a short terminal portion of stem surrounded by young leaves; similarly a rhizome or tuber, although technically a stem, is attacked more by root pests than those usually associated with stems.

For convenience of handling, the data on damage are grouped under the following headings:

Damaged leaves (1) – mostly by biting insects
Damaged leaves (2) – by sap-sucking insects and mites
Damaged shoots and buds (including flowers)
Damaged stems
Damaged fruits and seeds
Damaged roots and tubers (and bulbs)
Damaged seedlings and sown seeds

Damaged leaves (1) – mostly by biting insects (fig. 8, 9)

(a) Margin with regular notches (1): many adult broad-nosed weevils (Coleoptera: Curculionidae) feed on the leaf margins of many different plants throughout the World, producing characteristic notches.

(b) Margin with large, clean, semicircular (or subcircular) pieces of lamina missing: adults of leaf-cutting ants (Formicidae: Attinae) in C. and S. America, and leaf-cutting bees of the genus *Megachile*.

(c) Margin irregularly eaten (1, 4, 9.7): the commonest form of leaf damage by defoliating pests, caused by grasshoppers, locusts, many caterpillars, leaf-beetles, sawfly larvae, some slugs and snails, some birds; in a severe attack the entire leaf lamina may be eaten away, sometimes leaving only the main veins intact.

(d) Lamina skeletonized (7, 8, 12, 9.7): caterpillars of several families (Epiplemidae, Bombycidae, Noctuidae etc.) especially when young, eat part of the way through the leaf lamina but leave the veins and one epidermis intact; some beetles (adults and larvae of *Epilachna* (9.8)), adult Citrus Flea Beetle and some slug sawflies (Tenthredinidae).

(e) Lamina holed (8, 9): many tiny holes are made by adult flea beetles (Chrysomelidae, Halticinae); fewer larger holes are made by adults of tortoise beetles and some other Chrysomelidae, and some caterpillars (8).

(f) Lamina windowed (8): a window is a small hole in the lamina with one epidermis left intact, but after a while the thin epidermis dries and ruptures leaving a small hole; such damage is characteristic of larvae of the Diamond-back Moth.

(g) Leaves and shoot webbed: some caterpillars (Tortricidae, Pyralidae, Lasiocampidae, etc.) web leaves and shoots with silk and make a 'tent' or web in which they live and eat the leaves, often the web traps a large number of faecal pellets.

(h) Lamina mined (17, 18, 9.15): the mines may be either tunnel mines or blotches, sometimes starting as a tunnel and ending as a blotch mine; tunnel mines with a central line of faecal pellets usually belong to caterpillars (Lepidoptera: Gracillariidae, Lyonetidae, etc.); tunnels without evident faecal pellets are made by maggots (Diptera: Agromyzidae, Anthomyiidae, Ephydridae) and beetle larvae (Hispinae, Halticinae).

(i) Lamina cut and rolled or folded (5, 9.9): caterpillars of Hesperiidae (skippers), some Tortricidae and Pyralidae cut the lamina and make a leaf-roll, binding the edges with strands of silk; commonest examples are Cotton Leaf-roller (*Sylepta derogata*) on cotton and *Hibiscus*, banana skippers (*Erionota* spp.) and the several rice skippers; the leaf lamina is eaten within the protection of the roll.

(j) Cereal leaf with a linear series of small regular holes (19): made by young larvae of stem borers (Lepidoptera: Pyralidae, Noctuidae) before they penetrate the stem.

(k) Cereal or grass leaf with longitudinal scarification (9): feeding scars of some beetles (adults and larvae of *Oulema*, etc.); larval mines in such leaves (and Palmae) made by larvae of Hispinae (Coleoptera, Chrysomelidae), or Agromyzidae.

(l) Onion leaf with holes and internal feeding scars: made by various leaf-eating caterpillars (Noctuidae, etc.).

(m) Fruit tree leaves cut and folded, or webbed together, often with faecal pellets evident: made by larvae of various fruit tree tortricids.

(n) Tree leaf with interveinal area mined, tunnelled or skeletonized: caused by a single caterpillar of some Tortricidae, or by single sawfly larva (Tenthredinidae).

(o) Tiny or small bagworm cases (made of silk and plant fragments) adjacent to leaf lamina damage (holing or skeletonization) (9.3): made by caterpillars of some Microlepidoptera (Coleophoridae, etc.), some Pyralidae (*Nymphula* spp.) and some small species of Psychidae.

(p) Large bagworm cases, dangling from twigs, adjacent to leaves with lamina extensively eaten (9.4): large bagworms (Lepidoptera, Psychidae), most abundant in warmer climates.

(q) Leaflet rolled longitudinally and eaten: leaf-rolling sawfly larvae (*Blennocampa* spp.).

(r) Leaflet folded longitudinally, sometimes swollen and discoloured (galled): larvae of some Cecidomyiidae (several on clovers), and some leaf-rolling thrips (Phlaeothripidae).

Fig. 8. Damaged leaves (no.1).

1. Leaf margin notched (adult broad-nosed weevils: Coleoptera; Curculionidae).
2. Leaf axils with frothy spittle mass (spittle bugs: larvae of Cercopidae; Hemiptera).
3. Leaf lamina scarified (adults and nymphs of thrips: Thysanoptera. Red Spider Mites: Acarina; Tetranychidae).
4. Leaf edges curled under (aphids, jassids, psyllids and thrips: Hemiptera; Aphididae, Cicadellidae, Psyllidae, and Thysanoptera).
5. Dicotyledonous leaf rolled longitudinally (leaf-rollers – larvae of some Pyralidae and Tortricidae; Lepidoptera; Cotton Leaf-roller (*Sylepta derogata*) on cotton and *Hibiscus*).
6. *Citrus* leaf lamina with ventral pits (some pysllids (*Trioza* spp.): Hemiptera; Psyllidae).
7. Leaf lamina with many, small (shot) holes (adult flea beetles: Coleoptera; Chrysomelidae; Halticinae).
8. Leaf lamina with larger, regular-shaped holes (adults and some larvae of leaf beetles, especially tortoise beetles: Coleoptera; Chrysomelidae; Cassidinae).
9. Cereal leaf with elongate, deep scarification (adult and larvae of some leaf beetles: Coleoptera; Chrysomelidae) or elongate mines (larvae of hispid beetles: Coleoptera; Chrysomelidae, Hispinae).
10. Leaves completely folded, rolled or distorted into a bunchy lump (adult and nymphal thrips: Thysanoptera; Phlaeothripidae).
11. Wart-like outgrowths on underside of leaves (gall mite erinia: Acarina; Eriophyidae).
12. Leaf lamina extensively skeletonized (leaf skeletonizers: larvae of various Lepidoptera; Epiplemidae, Bombycidae, etc.)
13. *Brassica* leaf lamina with many, small, round holes and windows (Diamond-back Moth larvae (*Plutella xylostella*): Lepidoptera; Yponomeutidae).
14. Vegetable leaf with large pieces eaten away (leafworms, etc. : Lepidoptera; Noctuidae).
15. Leaf lamina with many round or elongate galls (gall midges and gall wasps: Diptera; Cecidomyiidae: Hymenoptera; Symphyta and Chalcidoidea, or by some Psyllidae, or gall mites (Eriophyidae).
16. Leaf lamina tattered with many irregular tears and holes (capsid bugs: Hemiptera; Miridae, etc.)
17. Leaf-mine starting as a tunnel and ending as a blotch-mine (larvae of Lyonetidae and Gracillariidae; Lepidoptera. Anthomyiidae; Diptera).
18. Leaf-mine with broad tunnel and central row of continuous faecal pellets, and edge of lamina turned over dorsally for pupation site (larvae of Gracillariidae; Lepidoptera).
19. Graminaceous leaf with regular series of small holes in expanding lamina (feeding holes of young stalk borers prior to penetration of the plant stalk: Lepidoptera; Noctuidae and Pyralidae).

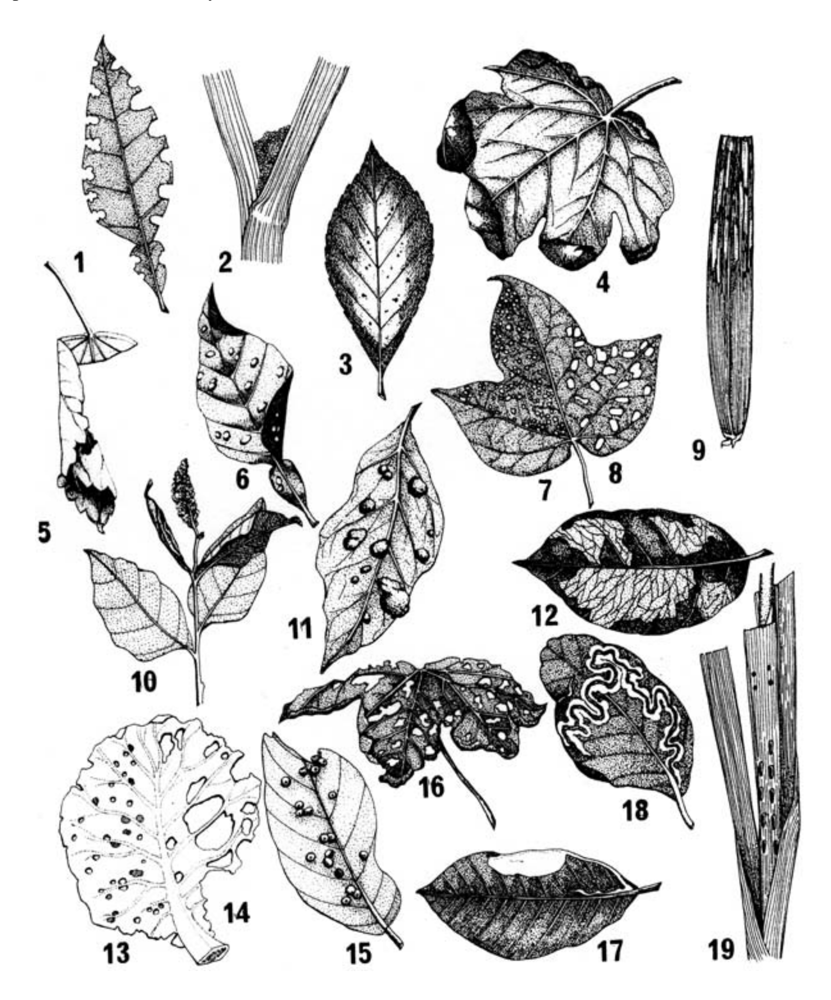


Fig. 9. Damaged leaves (no.2; including flowers).

1. Graminaceous leaf cut laterally and rolled longitudinally (larvae of some skippers: Lepidoptera; Hesperiidae).
2. Graminaceous leaf with edges folded inwards (larvae and pupae of skippers, and egg site of some Pyralidae: Lepidoptera).
3. Small leaf-cases on rice leaves (Rice Caseworm (*Nymphula depunctalis*): Lepidoptera; Pyralidae).
4. Palm leaves eaten and small bagworm cases (bagworms: Lepidoptera; Psychidae).
5. Leaf edge rolled dorsally (nymphs of Aleyrodidae, thrips, and spiders nests).
6. Large buds bored (budworms: Lepidoptera; Tortricidae).
7. Leaf lamina extensively eaten away (large caterpillars: Lepidoptera; Noctuidae, Sphingidae, etc. Grasshoppers and locusts: Orthoptera; Acrididae. Adult scarab beetles: Coleoptera; Scarabaeidae).
8. Leaf lamina with ladder-like windowing leaving veins intact (adults and larvae of epilachna beetles (*Epilachna* spp.): Coleoptera; Coccinellidae).
9. Banana leaf with lamina cut and rolled (banana skippers (*Erionota* spp.): Lepidoptera; Hesperiidae).
10. Shoot telescoped, small distorted leaves, reduced flowers (mealybugs: Hemiptera; Pseudococcidae).
11. Leaf lamina covered dorsally with black growth (sooty mould, grows on honey-dew excreted by various Homoptera; Aphididae, Coccidae, Pseudococcidae, etc.)
12. Flower bud eaten into, leaving large jagged hole (various caterpillars: Lepidoptera; Noctuidae, Pyralidae, etc. Grass-hoppers: Orthoptera; Tettigoniidae).
13. Flower petals with small holes (adult flower beetles: Coleoptera; Scarabaeidae; Rutelinae).
14. Flower perianth largely destroyed (adult blister beetles: Coleoptera; Meloidae).
15. Tunnel leaf mine with no central line of faecal pellets (dipterous leaf miners: Diptera; Agromyzidae, Anthomyiidae, Ephydridae, etc.).
16. Graminaceous leaves with longitudinal streaking (streak viruses, transmitted by Cicadellidae, Aphididae, etc.).
17. Plant leaves silvered and wilting (thrips, especially Onion Thrips (*Thrips tabaci*): Thysanoptera).



Damaged leaves (2) – by sap-sucking insects and mites (fig. 10)

(a) Leaf curled under (1) or generally distorted, sometimes completely distorted into a bunchy lump of tissue (11): the former damage is done by Aphididae, Psyllidae, Aleyrodidae, Cicadellidae and some other Homoptera, the latter damage is by thrips of the family Phlaeothripidae, and some aphids.

(b) Leaf folded (2) by aphids; folded and galled (5) by *Trioza* psyllids; folded or rolled longitudinally (3) by nymphs of some Aleyrodidae, some thrips, or spiders making a nest.

(c) Leaf lamina with red blisters projecting dorsally (4): Red Currant Blister Aphid, and some gall mites (Eriophyidae).

(d) Lamina pitted: some Psyllidae in the group Triozinae cause ventral leaf-pits at the sites where the nymphs sit and feed, young leaves sometimes may be considerably deformed (mostly tropical).

Fig.10. Damaged leaves (2) – by sap-sucking insects and mites.

1. Leaves with curled-under edges, somewhat distorted, sometimes discoloured; caused by sap loss from feeding aphids, psyllids, cicadellids and some thrips.
2. Leaf of pear with characteristic curled shape, caused by feeding of Pear–Bedstraw Aphid (*Dysaphis pyri*); many fruit trees show specific distortion of leaves by various aphids. (See also 21–5.)
3. Leaf edge rolled dorsally, by nymphs of some Aleyrodidae, thrips (some Phlaeothripidae), some aphids; spiders make nests sometimes in rolled leaves.
4. Leaf with many small distinct blisters, bright red in colour, caused by colonies of Redcurrant Blister Aphid on the underside; slightly similar small/tiny bright red galls are caused by some gall mites (Eriophyidae), but mostly on shade and est trees.
5. with edge rolled, distorted and coloured (reddish), forming a definite gall; nymphs of *Trioza alacris* on Bay leaves, and similar leaf galls are made by some other species of *Trioza* (Psyllidae). A few similar leaf galls are made by Cecidomyiidae.



Fig.10. (continued).

6. A spittle mass under or on the leaf surface, made by certain spittle bugs (Cercopidae), in this case *Philaenus spumarius* on strawberry. (Large frothy clumps on plant foliage in the tropics are usually the egg masses of tree frogs!)
7. Leaves with many small necrotic black spots, usually causing death of the leaf; the drawing shows leaves of Tea after feeding by *Helopeltis* bugs (Heteroptera, Miridae); many Heteroptera with their toxic saliva cause necrotic spots where they feed, especially some Pentatomidae, Coreidae, Lygaeidae, Miridae, etc.; some adult Cercopidae also cause leaf spotting.
8. Leaf with lamina tattered; caused by feeding of Heteroptera on young leaf, toxic saliva causes necrotic spots that become holes and as the young leaf expands the holes tear and enlarge, causing 'tattering'; this drawing shows damage to leaf of Runner Bean by Common Green Capsid.
9. Leaf with covering of black sooty mould growing on the honeydew excreted by various Homoptera; usually an indication of infestation higher on the plant by aphids, mealybugs, whiteflies, or soft scales.
10. Leaf surface scarified, with a shiny silvery appearance and often wilting somewhat; damaged by feeding thrips (Thripidae). (See also 20–15).
11. Leaf sometimes rolled longitudinally and/or else very severely distorted; colonies of some thrips in the family Phlaeothripidae; also a few aphids can cause such distortion (e.g. Plum Leaf-curling Aphid) (see fig. 21–5).
12. Onion (and other monocotyledons) leaf speckled and scarified and eventually severely wilting, due to feeding of Onion Thrips (*Thrips tabaci*).
13. Leaf petiole galled; this is a poplar leaf galled by Lettuce Root Aphid (*Pemphigus bursarius*) spring generation. Leaf petioles are bored or mined by various caterpillars (Lepidoptera, Gelechiidae, etc.) and some beetle larvae (Coleoptera, Curculionidae, etc), but most are to be found on wild plants.
14. Petiole of bean leaf galled by second generation Bean Fly larvae (Agromyzidae).
15. Leaf surface scarified, often with a silvery or a bronzed appearance, usually wilting somewhat, and often with a film of silk webbing over the surface; typical Red Spider Mite damage (*Tetranychus* spp. etc., Tetranychidae); often moulted 'skins' (exuviae) on the leaf surface.
16. Young leaf severely distorted and crinkled in appearance; dwarfed; typical damage by Strawberry Mite (*Stenotarsonemus pallidus*, Tarsonemidae) and other tarsonemids.
17. Warty outgrowths, usually on underside of leaves but projecting dorsally, termed erinia, made by gall mites (Acarina, Eriophyidae); usually many mites per erinium, but on Sycamore the tiny red galls contain only single mites. Many different sizes/shapes/colours are to be found on leaves galled by Eriophyidae.
18. Leaf with definitely shaped galls on either upper or lower surface, sometimes distinctively coloured (often red); the economic species are mostly gall midges (Diptera, Cecidomyiidae), but spectacular woodland (temperate) species include the oak leaf galls made by Cynipidae, and the red willow leaf-galls made by *Pontania* (Hymenoptera, Tenthredinidae).
19. Leaves, both monocotyledons and dicotyledons, with striking discoloration between the veins indicating that the plant is suffering a virus infection, usually transmitted by a homopterous bug (aphid, whitefly, leafhopper, etc.) in its feeding activity; the coloration pattern is usually linear in monocotyledons and reticulate on broad leafed dicotyledons. Deficiency of some minerals may produce a similar effect on some plants.

(e) Lamina scarified (10, 15): adults and nymphs of some thrips (Thysanoptera) and some spider mites (Tetranychidae) make tiny epidermal feeding lesions which give the lamina a silvery, bronzed or scarified appearance; soft leaves will be caused to wilt, as shown by Onion Thrips on onions (12).

(f) Lamina with erinia (17): on the lower surface (usually) of some leaves are found wart-like out-growths (erinia) inhabited by microscopic gall mites (Eriophyidae).

(g) Leaf galls (18): round or elongate galls, small or large, few or numerous, found on either upper or lower leaf surface, sometimes arranged randomly, sometimes distributed peripherally or alongside veins; made by feeding larvae of gall midges (Diptera: Cecidomyiidae), gall mites (Acarina: Eriophyidae), gall wasps (Hymenoptera: Chalcidoidea, Cynipoidea and Symphyta) and some Psyllidae.

(h) Lamina tattered with irregular holes and tears (8): margin usually intact; many Miridae and other Heteroptera feed on young leaves, and their toxic saliva results in small necrotic spots. As the leaf grows and expands the dead areas enlarge and tear, resulting in the characteristic tattering of the expanded leaf.

(i) Leaf with numerous small necrotic dark spots (7): caused by toxic saliva of *Helopeltis* and other Miridae.

(j) With bubble-froth (6) either on leaves or in leaf axils: spittle mass built by nymphs of Cercopidae (spittle bugs) for protection.

(k) With black sooty mould (9): infestations by aphids, mealybugs, and soft scales are often associated with sooty moulds that develop on the sugar excreted as 'honey-dew'.

(l) Leaf petiole galled: several species of temperate woolly aphids (Pemphigidae) make large galls in the leaf petioles of various woody shrubs and trees (13); also Bean Fly larvae mine and swell petioles of beans (14).

(m) Leaf dwarfed, crinkled and distorted (16): Strawberry Mite, and other Tarsonemidae.

(n) Cereal leaves with longitudinal streaking (adjacent pale and dark areas) (19), and dicotyledonous leaves with a conspicuous regular blotching: these are symptoms of virus infection; all plant viruses are transmitted by feeding Hemiptera, or sometimes by nematodes, or occasionally by beetles.

Damaged shoots and buds (including flowers) (fig. 11)

(a) Shoot killed distally (brown and wilted) (1): by boring larva of *Earias* spp. in cotton (spiny boll-worms), larvae of longhorn beetles (Cerambycidae), caterpillars of goat and leopard moths (Cossidae); sometimes killed by ovipositing cicadas or Tettigoniidae; also killed by toxic saliva of some sap-sucking bugs (Coreidae, Pentatomidae, etc.) (3).

(b) Cereal or grass seedling with 'dead-heart' (2): caused by boring larva of shoot flies (Agromyzidae, Anthomyiidae, Muscidae, etc.); also by caterpillar of some Pyralidae and Noctuidae (stem borers).
(c) Shoot and apical leaves completely distorted, crinkled and small (5): caused by Plum Leaf-curling Aphid and Green Apple Aphid; similar damage caused by some leaf-rolling thrips (Phlaeothripidae).
(d) Petals gnawed (12, 13): adult blister beetles (Meloidae) chew petals of many plants, often common on Malvaceae; adult flower beetles (Scarabaeidae) make small holes in petals, *Popillia* being especially injurious.
(e) Petals scarified: flowers of Leguminosae, Compositae, etc. inhabited by adults and nymphs of thrips (Thripidae) which scarify the bases of the petals.
(f) Flowers inhabited by tiny black beetles, making feeding scars at the base of the petals: legume flowers inhabited by *Apion* weevils; worldwide.
(g) Anthers eaten: pollen beetles (*Coryna* spp. etc.) feed on the anthers of many flowers, especially Malvaceae, destroying the pollen sacs.
(h) Maize tassels eaten: by grasshoppers, or Maize Tassel Beetle in East Africa, or Japanese Beetle in the USA.
(i) Flowers inhabited by tiny maggots: gall midge larvae (Diptera: Cecidomyiidae), either white, yellow, orange or red in colour, usually causing shoot and flower deformation (nettlehead).
(j) Buds bored (8): caterpillars of some Tortricidae bore into large buds of shrubs and trees (called 'budworms' in the USA).
(k) Flower buds (rape) bored by blossom beetles (*Meligethes* spp.) (9): larvae develop inside unopened buds.
(l) Grass or cereal shoot galled and swollen (7): caused by some grass gall flies (*Chlorops* spp. etc.).
(m) Flower bud (apple) 'capped' (11): caused by adult Apple Blossom Weevil, larvae develop inside unopened bud, feeding on the flower.
(n) Buds gnawed, with large holes (6): eaten by large caterpillars (e.g. Cotton Semi-looper, *Anomis flava*, Noctuidae); sometimes by long-horned grasshoppers (Orthoptera: Tettigoniidae).
(o) Buds webbed and gnawed: some Tortricidae have caterpillars that feed on opening buds which they cover with a fine silk webbing.
(p) Buds pierced and dying: feeding adult and nymphal jassids (Miridae) and other Heteroptera, with their toxic saliva.
(q) Buds enlarged and swollen (10): gall mites of the family Eriophyidae infest buds of some shrubs causing a disorder called 'big-bud'.
(r) Buds and shoots stunted/wilting (4): heavy infestations of aphids, scales, mealybugs, can stunt young shoots during active growth; Hibiscus Mealybug is unusual in causing severe shoot telescoping and often shoot death; 'nettleheads' caused by larvae of Cecidomyiidae in many cultivated plants.
(s) Woody shoot cut off (14): twig cut by adult twig-cutter weevils (*Rhynchites* spp.) after ovipositing in distal part of shoot.

Damaged stems (fig. 12)

These fall into four main categories for practical purposes: shoots of graminaceous seedlings; stems of cereals and grasses; shoots and twigs of shrubs; trunks and branches of trees (and large woody shrubs).

(a) Cereal shoots with 'dead-hearts' (fig. 6): caused by boring larvae of shoot flies (Agromyzidae, Muscidae, Anthomyiidae), and caterpillars of Pyralidae.
(b) Cereal stems galled and distorted: larvae of Diptera (Opomyzidae, Chloropidae); cereal stem gall midges (Cecidomyiidae) are mostly temperate in distribution.
(c) Cereal and grass stems bored (11): caterpillars of the family Pyralidae generally bore rice and grass stems, while the larger caterpillars of the Noctuidae bore stalks of maize, sorghum and other larger species of Gramineae; tunnels in sugarcane are usually very short because the stem is solid and pithless. Stem sawflies (*Cephus*) bore apically in temperate cereals, especially wheat.
(d) Herbaceous stems and woody shoots bored, swollen often with a single emergence hole: larvae of gall weevils (Curculionidae) (16), also Sisal Weevil, and the temperate Cabbage Stem Weevil and Turnip Weevil (5).
(e) Banana pseudostem bored: Banana Stem Weevil (*Odoiporus longicollis*) larvae make extensive tunnel galleries in which they pupate and adults may also be found.
(f) Herbaceous stems, including Sweet Potato stem (vine) bored (2): caterpillars of some clearwing moths (Sesiidae) and plume moths (Pteryphoridae), also some weevils and some sawfly larvae.
(g) Twigs galled (9): made by feeding larvae of gall midges (Diptera: Cecidomyiidae), some gall wasps (Cynipidae, Eurytomidae, Torymidae), old galls have multiple exit holes; a few twig galls are made by weevil larvae and some woolly aphids (Pemphigidae).
(h) Stems (often Gramineae) with frothy spittle mass in the axils; made by nymphs of Cercopidae (spittlebugs).
(i) Seedling stem gnawed at about ground level, commonly sugarbeet gnawed by adults of Pygmy Mangold Beetle (*Atomaria linearis*) (4); similar damage done by wireworms (Coleoptera, Elateridae), symphylids (Myriapoda), and some other soil pests.
(j) Tree trunk and branches bored, sometimes bark eaten externally: timber borers belong to two orders of insects, the Lepidoptera and Coleoptera; Metarbelidae feed externally at night on the bark under a silken tube coated with frass but retire during the day to a deep tunnel in the heartwood (tropical); larvae of Cossidae and some Sesiidae bore in the heartwood of trunks and usually down the centre of smaller branches (13); the circular adult emergence hole typically contains the

Fig. 11. Damaged shoots and buds (including flowers).

1. Distal part of woody shoot wilting and dying: some longhorn beetle larvae (Coleoptera, Cerambycidae); spiny bollworms (*Earias* spp.) on cotton, boring inside the stem; also larvae of goat moths and leopard moths (Lepidoptera, Cossidae); shoot also killed by ovipositing cicadas.
2. Cereal or grass shoot dead and brown ('deadheart'): shoot growing point eaten by larvae of shoot flies (Anthomyiidae, Muscidae, etc.); or stem borer caterpillars (Lepidoptera, Pyralidae, Noctuidae).
3. Woody or herbaceous stem with apical part wilting and killed: various Heteroptera with toxic saliva (mostly Coreidae, also Pentatomidae, Lygaeidae, etc.).
4. Apical shoot distorted, dwarfed, telescoped, often referred to as a 'nettlehead' condition: the illustration shows the effect on a *Hibiscus* shoot of the mealybug *Maconellicoccus hirsutus* (unusual in having toxic saliva), but only a light infestation; such shoot deformation may be produced by some aphids, but more commonly by Cecidomyiidae (Pea Midge, Hawthorn Shoot Gall Midge, etc.), as a result of the saliva of the feeding larvae; the 'nettlehead' is usually a tight rosette of small leaves.
5. Apical shoot and young leaves completely distorted, crinkly, small and deformed: Plum Leaf-curling Aphid is one of the aphids that has toxic saliva; shoot may die.
6. Flower bud eaten into, by various grasshoppers, some caterpillars (Noctuidae, etc.), and some beetles (*Popillia* etc., Scarabaeidae).
7. Grass or cereal shoot galled, swollen and telescoped: caused by larvae of Gout Fly (*Chlorops* spp.), and a few other grass flies; Psyllidae of the genus *Livia* cause similar galls on *Juncus* spp. but not on cereals.
8. Flower bud bored by small caterpillars belonging to the Tortricidae, collectively called 'budworms', often frass outside the hole.
9. Rape flower buds bored by adult blossom beetles (*Meligethes* spp.) larvae feed on developing flower internally. Other pollen beetles may feed on exposed anthers after flower has opened.
10. Bud swollen and distended but does not open; this is the 'big-bud' condition produced on various shrubs by mites of the genera *Phyllocoptella* and *Cecidophyopsis* (on Hazel and Blackcurrant).
11. 'Capped' flower bud, turning brown, and does not open, produced by larva of Apple Blossom Weevil (*Anthonomus pomorum*).
12. Flower with small holes in the petals, sometimes numerous; made by adult flower beetles, especially *Popillia* (Scarabaeidae, Rutelinae); also some adult and larval tortoise beetles (Chrysomelidae, Cassidinae).
13. Flower with large pieces of perianth removed: eating by adult blister beetles, especially *Mylabris* and *Epicauta* (Meloidae), sometimes the entire flower is destroyed.
14. Woody twig cut through and apical shoot fallen or dangling: this is done by adult weevils after laying an egg in the terminal part of the stem, the larva develops inside the fallen piece of stem; seen on apple by Twig Cutter (*Rhynchites caeruleus*). Some shoot weevil larvae live inside the intact stem, which is killed distally by their feeding activity (e.g. Bamboo Shoot Weevil); but most stem weevils do not actually kill the plant distally.

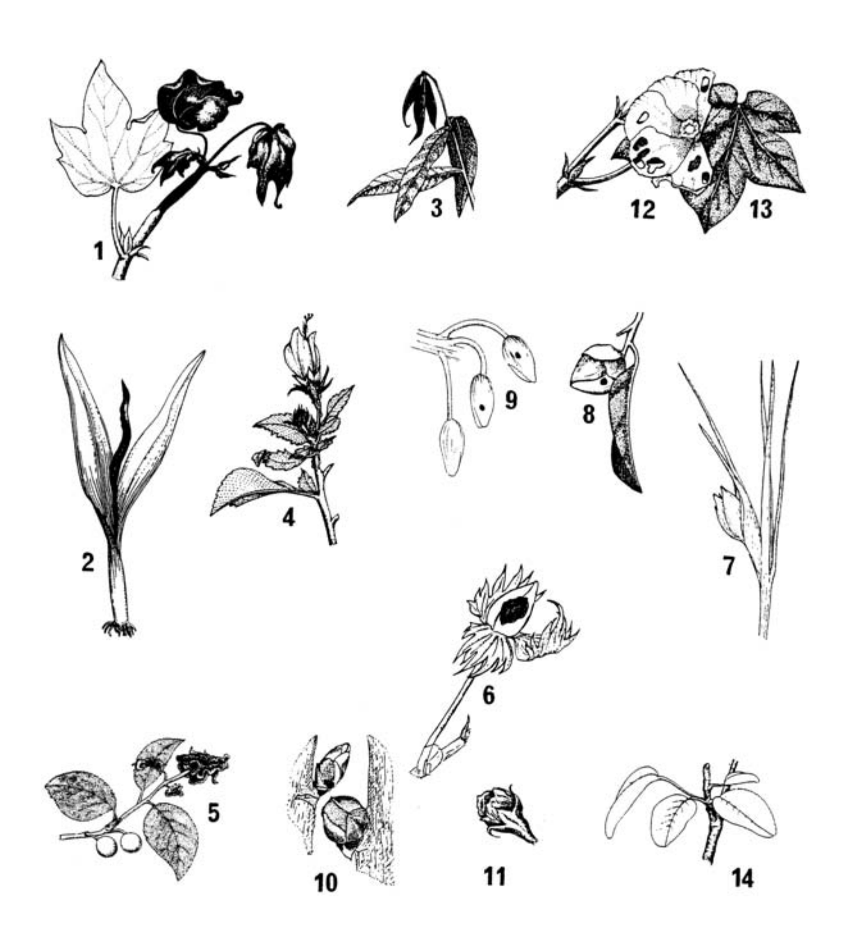
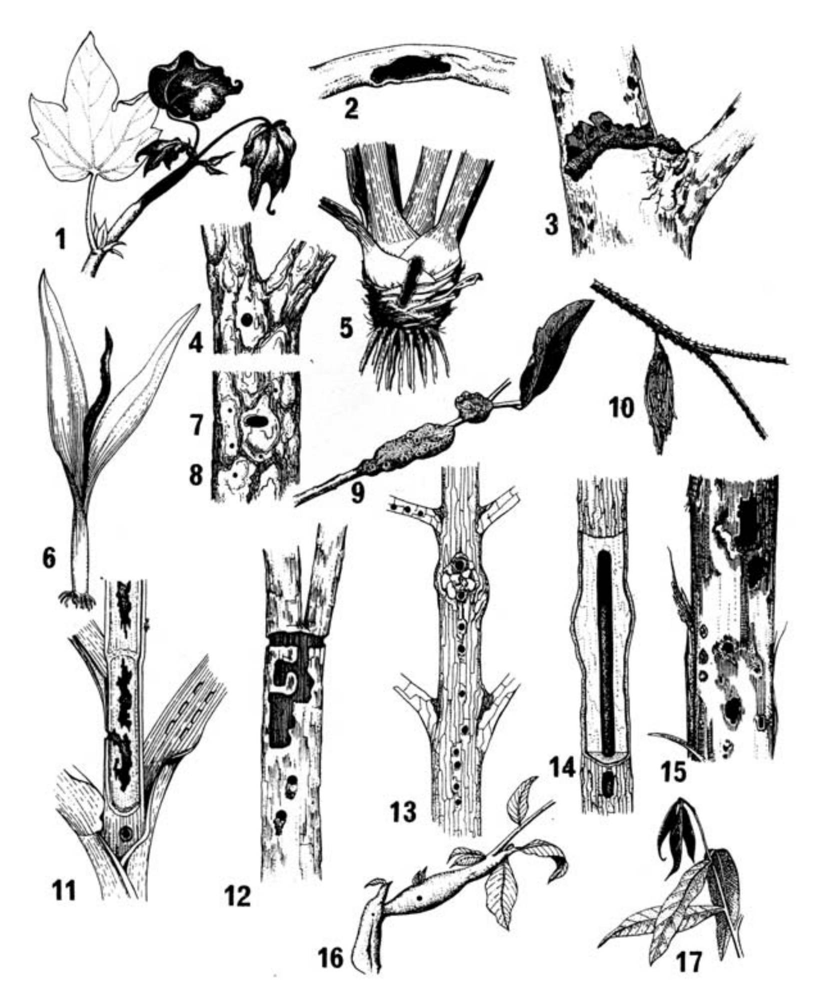


Fig. 12. Damaged stems.

1. Apical part of stem bored and dying (spiny bollworms in cotton (*Earias* spp.). larvae of some longhorn beetles: Coleoptera; Cerambycidae).
2. Sweet potato vine bored (caterpillars of clear-wing moths; Sesiidae, and plume moths; Pteryphoridae).
3. Tree trunk or branch with eaten bark and deep holes into the wood, with a frass and silk tube (Wood-borer Moth (*Indarbela* spp.): Lepidoptera; Metarbelidae).
4. Tree trunk or branch with single round emergence hole from 4–25 mm diameter (longhorn beetles: Coleoptera; Cerambycidae). With a pupal exuvium protruding from the hole (clear-wing moths: Lepidoptera; Sesiidae. Goat or leopard moths: Lepidoptera; Cossidae).
5. Sisal stem bored internally (larvae of Sisal Weevil (*Scyphophorus interstitialis*): Coleoptera; Curculionidae).
6. Graminaceous seedling with 'dead-heart' (larvae of root fly: Diptera; Anthomyiidae. Muscidae, etc. Or stem borer caterpillar: Lepidoptera; Pyralidae, Noctuidae).
7. Woody stem with oval emergence hole (jewel beetle: Coleoptera; Buprestidae).
8. Woody stem with small circular holes in the bark (bark beetles: Coleoptera; Scolytidae).
9. Twig with round or irregular galls, old galls with small emergence holes (gall midges: Diptera; Cecidomyiidae. Gall wasps: Hymenoptera; Cynipidae, Eurytomidae, etc.).
10. Twig with bagworm case (bagworm: Lepidoptera; Psychidae).
11. Graminaceous stem bored internally, with emergence holes to exterior (stalk borers: Lepidoptera; Pyralidae, Noctuidae).
12. Tree or woody stem with sapwood eaten away in patches and some deep tunnels (longhorn beetle larvae: Coleoptera; Cerambycidae).
13. Tree branches or trunk bored centrally with a line of frass holes to the exterior (longhorn beetle larvae: Coleoptera; Cerambycidae).
14. Tree branch or stem bored with a cylindrical tunnel (Black Borer adults (*Apate* spp.): Coleoptera; Bostrychidae. Larvae of leopard or goat moths: Lepidoptera; Cossidae, or clear-wing moth; Sesiidae)
15. Banana 'stem' extensively bored and tunnelled (larvae and adults of Banana Stem Weevil (*Odoiporus longicollis*): Coleoptera; Curculionidae).
16. Twig or woody stem with elongate swelling, sometimes with a single emergence hole (gall weevils (several species) : Coleoptera; Curculionidae).
17. Woody stem with apical shoots killed and wilting (coreid bugs with their toxic saliva: Hemiptera; Coreidae).



pupal exuvium projecting. Tree-boring beetles belong mainly to the families Cerambycidae, Buprestidae, Bostrychidae, and Scolytidae, with a few weevils (Curculionidae) and a few small families such as the Lymexylidae. Cerambycidae are longhorn beetles and may be very large (*Batocera* spp.) with larvae that bore in trees for up to 3–4 years before pupating; they mostly eat sapwood just under the bark and may leave frass holes to the exterior; the emergence hole is circular (4, 13); the adults sometimes chew patches of bark. Buprestidae are called jewel beetles, and the larvae, known as flat-headed borers, and the emerging adults leave an oval exit hole in the tree bark (7). Bostrychidae are black, cylindrical beetles, completely circular in cross-section and the tunnels are bored by the adult beetles (14) called black borers. Scolytidae (shot-hole and twig borers) belong to the group of ambrosia or fungus beetles; the adults bore into trees (8) and make extensive breeding galleries under the bark; they carry fungus spores on their bodies with which to inoculate the new fungus galleries where the larvae feed; some species bore down the centre of twigs on bushes such as tea.

Damaged fruits and seeds (fig. 13)

(a) Cereal panicle with few grains developed, or grains small and distorted: larvae of Sorghum Gall Midge (*Contarinia sorghicola*; Diptera: Cecidomyiidae); small distorted grains of wheat, sorghum, etc.,

(b) Fruits with numerous small necrotic patches: heteropteran bugs of the families Miridae, Coreidae and Pentatomidae have toxic saliva, and when feeding on fruits they cause necrosis at the feeding sites, which usually become infected with fungi and bacteria, resulting in rotting, death, and premature fruit-fall, e.g. cocoa capsids, cotton stink bugs (3, 4) Apple Capsid, and *Cercopis* adults (froghoppers).

(c) Fruits, nuts and seeds bored: bored internally by weevil larvae, and hole made by larva or adult, examples are mango weevils, Hazel-nut Weevil (13), Cotton Boll Weevil (8), Maize Weevil (12); in small ovaries one weevil larva will eat all the endosperm and thus each ovary contains only one weevil pupa (e.g. clover seed weevils: *Apion* spp.); several Maize Weevils can develop in one maize kernel.

(d) Fruits with large internal tunnels, sometimes large holes to the exterior (5, 7, 8, 9), sometimes infected with fungal and bacterial rots, sometimes frass expelled: made by caterpillars of the families Tortricidae, Pyralidae and Noctuidae; eggs are laid externally, and the tiny caterpillars (first instar) bore into the fruit; sometimes infested fruits fall prematurely; cotton bolls bored by many bollworms; top fruit bored by many different tortricid larvae (7) but Codling Moth is the most serious pest.

(e) Pulse pods bored by many different caterpillars: large Noctuidae (17) too stout to enter the pods make holes and reach into the young seeds which are eaten; pea moths (*Cydia* spp.) live inside the pods (16) and eat the seeds, as does Pea Pod Borer (*Etiella*, Pyralidae); many of the Lycaenidae have larvae feeding on or in the pods of Leguminosae.

(f) Fruits webbed and gnawed (6): some caterpillars (mostly Pyralidae) will spin silk over young fruits and feed on the fruits (Coffee Berry Moth: *Prophantis smaragdina*, Pyralidae); Sesame Webworm spins silk over the pod and shoot before boring the pod. Apples and other fruits with surface damage due to feeding caterpillars (Tortricidae), usually under a leaf webbed to the fruit.

(g) Fruitlets (apple, etc.) gnawed: by adult chafer beetles (Scarabaeidae) in the spring.

(h) Fruitlets bored and with surface feeding scars: made by feeding larvae of Apple Sawfly (*Hoplocampa* spp.).

(i) Fruits tunnelled and bored: adults of some Scolytidae bore host plants to make breeding tunnels and galleries in which the larvae develop; Coffee Berry Borer (*Hypothenemus hampei*) bore coffee berries in Africa and South America.

(j) Fruits with maggots inside, a necrotic area, and sometimes small holes (9): fruit flies of the family Tephritidae attack almost all larger types of fruit; eggs are laid under the skin of the young fruit and the fly larvae develop internally as the fruit ripens; the fruit often falls prematurely, pupation usually takes place in the soil; secondary infection of the tunnels and oviposition site by bacteria and fungi is common; typically there is neither frass hole, entrance nor exit hole evident in the skin of the fruit while still on the tree, but sometimes there may be sap exudation. Also Pear Midge, causing fruitlet fall.

(k) Cruciferous seed pods bored and with an emergence hole (12): made by emerging larva of Cabbage Seed Weevil (*Ceutorhynchus assimilis*) on its way to pupate in the soil.

(l) Pulse and cruciferous pods with internal damage made by tiny maggots, which are larvae of several pod midges (Diptera, Cecidomyiidae) and some Agromyzidae (pod flies).

(m) Fruits (apple, etc.) with small feeding scars: made by adults of some weevils (*Caenorhinus* spp.).

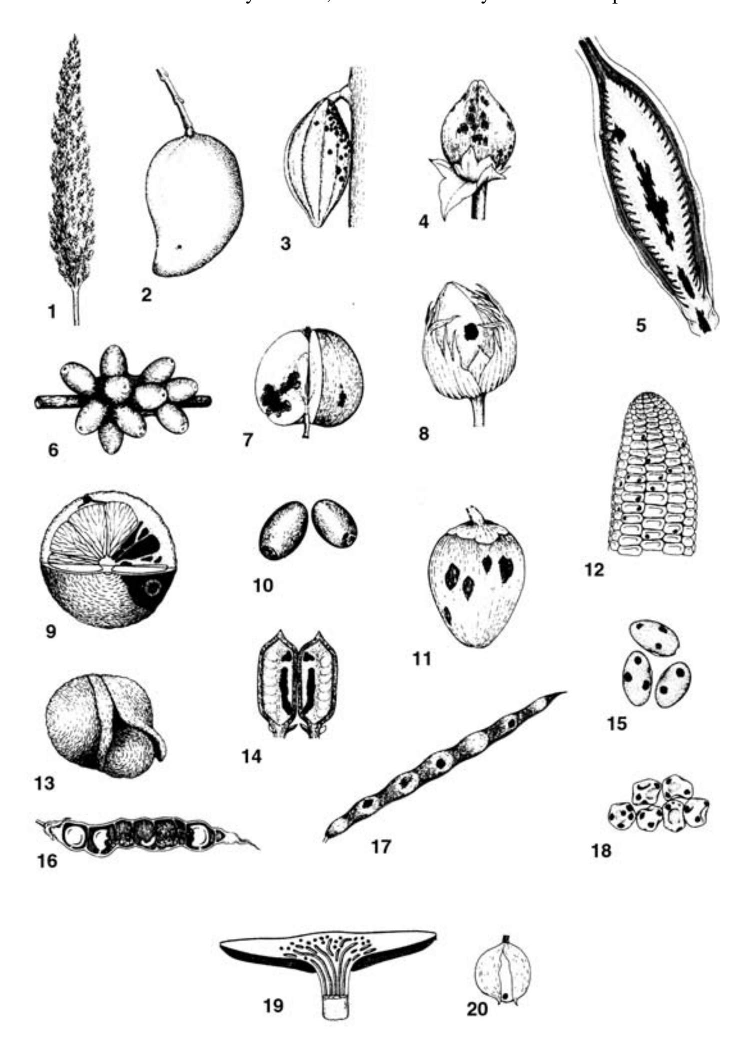
(n) Fruits (pea pods, etc.) with external scarification (11): caused by the feeding of some thrips (Thripidae).

(o) Fruit deformed (13): various phytophagous mites (Eriophyidae) feeding on flowers and young fruits cause distortion and deformation of the fruits.

(p) Mushroom fruiting body with extensive tunnelling in the cap and up the stalk (19): made by feeding larvae of the numerous ‘mushroom flies’ (Cecidomyiidae, Sciaridae, and Phoridae).

Fig. 13. Damaged fruits and seeds.

1. Sorghum grains destroyed in panicle (larvae of Sorghum Midge (*Contarinia sorghicola*): Diptera; Cecidomyiidae).
2. Mango fruit bored (larvae of Mango Weevil (*Cryptorrhynchus* spp.): Coleoptera; Curculionidae).
3. Cocoa pod with necrotic spots (feeding of nymphs and adult cocoa capsids: Hemiptera; Miridae).
4. Cotton boll with necrotic spots (caused by the toxic saliva of feeding stink bugs: Hemiptera; Pentatomidae).
5. Maize cob bored (larvae of American Bollworm (*Heliothis armigera*): Lepidoptera; Noctuidae).
6. Coffee berries webbed and gnawed (caterpillars of Coffee Berry Moth (*Prophantis smaragdina*): Lepidoptera; Pyralidae).
7. Apple bored (Codling Moth larvae (*Cydia pomonella*): Lepidoptera; Tortricidae).
8. Cotton boll bored (Cotton Bollworms: Lepidoptera; Noctuidae and Tortricidae).
9. Orange with necrotic area (caused by Fruit Fly maggots: Diptera; Tephritidae).
10. Coffee berries bored (adult Coffee Berry Borer (*Hypothenemus hampei*): Coleoptera. Scolytidae).
11. Coconut scarred (by toxic saliva from feeding Coconut Bug (*Pseudotheraptus wayi*): Hemiptera; Coreidae).
12. Maize cob with bored seeds (Maize Weevil (*Sitophilus zeamais*): Coleoptera; Curculionidae): holes made by emerging adults.
13. Orange fruit distorted (Citrus Bud Mite (*Aceria sheldoni*): Acarina; Eriophyidae).
14. Sesame pod bored (caterpillars of Sesame Webworm (*Antigastra catalaunalis*): Lepidoptera; Pyralidae).
15. Bean seeds windowed and holed (bruchids: Coleoptera; Bruchidae).
16. Pea (pulse) pod bored and seeds eaten (Pea Pod Borer (*Etiella zinckenella*): Lepidoptera; Pyralidae).
17. Bean (pulse) pod bored with large holes by the seeds (the large larvae of American Bollworm (*Heliothis armigera*): Lepidoptera; Noctuidae, and other Noctuidae).
18. Dried maize seeds bored (Maize Weevil (*Sitophilus zeamais*): Coleoptera; Curculionidae).
19. Mushroom tunnelled extensively; holes made by larvae (maggots) of several different flies; usually Sciaridae, Phoridae and Cecidomyiidae.
20. Macadamia fruit showing emergence hole made by full-grown caterpillar of *Cryptophlebia* spp. (Tortricidae) through this extremely hard nut shell; not all holes in hard nut shells are made by weevils, some are made by tortricid caterpillars.



(q) Pulse seeds, both inside ripening and ripe pods, and in storage with tunnels (15): made by larvae of several different species of Bruchidae; pupae to be found under the 'windows'; *Bruchus* spp. are more field pests, and *Callosobruchus* more adapted to life in stores.

(r) Maize with ripening seeds eaten in the field by boring larvae (12) of *Sitophilus zeamais*, then carried into grain store where further breeding continues (18).

(s) Various ripening seeds attacked in the field, hollowed out by feeding larvae of *Araecerus fasciculatus* (Coffee Bean Weevil).

(t) Nuts (in this case Macadamia) with kernel eaten and hole bored through the shell to the exterior (20): bored by caterpillar of various Tortricidae (*Cryptophlebia* spp.).

(v) Grains in store with 'windows' and hole bored (18): *Sitophilus* species with *S. granarius* preferring wheat, *S. zeamais* in maize and *S. oryzae* preferring rice, and the latter two species more tropical than the temperate grain weevil.

Damaged roots and tubers (and bulbs) (fig. 14)

(a) Fine roots eaten: by subterranean caterpillars, fly larvae, beetle larvae and termites.

(b) Tubers tunnelled (1–3): usually infected with secondary rots; Potato Tuber Moth larvae bore down the stem into the tubers.

(c) Tubers with narrow tunnels (2): bored by wire-worms (larvae of Elateridae) and some small species of slugs.

(d) Tubers with wide, sometimes shallow tunnels (1): bored by cutworms (Noctuidae), chafer grubs (Scarabaeidae), and some larger species of subterranean slugs.

(e) Yam tubers with wide tunnels: bored by adults and larvae of yam beetles (Scarabaeidae) (11).

(f) Sweet potato tubers bored: infected with secondary rots; larvae and adults of Sweet Potato Weevils (*Cylas* spp., Apionidae) (4).

(g) Root stock encrusted: root mealybugs form a hard layer of encrustation over plant roots; ants are often found in attendance; mostly tropical.

(h) Roots with waxy agglomeration: root aphids (usually Pemphigidae) found as a waxy or mealy agglomeration on roots of some herbaceous plants; mostly temperate.

(i) Roots galled (5): larvae of several weevils (*Ceutorhynchus* spp.) and other beetles live inside root galls; *Sitona* inside the 'nodules' on roots of Leguminosae.

(j) Taproot eaten or hollowed (8): cutworms (Noctuidae) and chafer grubs (Scarabaeidae), but in particular Rosy Rustic Moth larvae.

(k) Taproot tunnelled and eaten (8), symptoms are wilting and plant collapse: larvae of Anthomyiidae (root maggots), and other Diptera such as Carrot Fly maggots (*Psila rosae*) (9); with root crops, plant wilting does not normally occur.

(l) Bulb bored and tunnelled: Onion Fly (*Delia antiqua*) larvae (temperate and sub-tropical), and the temperate narcissus flies (Syrphidae).

(m) Rhizome bored: Banana Weevil (*Cosmopolites sordidus*) larvae bore the rhizome extensively, and both pupae and adults may also be found in the tunnels (10); various fly maggots belonging to the Chloropidae and other families bore the rhizomes of ginger.

(n) Roots with small globular cysts (7): although nematodes are not included in this book, mention of them cannot be avoided here; small globular cysts are produced by female *Heterodera* spp. (cysteelworms) on a wide range of host plants; probably more temperate than tropical.

(o) Roots with large swellings (5): root-knot nematodes (eelworms), *Meloidogyne* spp. cause extensive root swellings on many crop plants, especially in the tropics.

(p) Roots stunted but bushily prolific (6): various free-living nematodes.

Damage to seedlings and sown seeds (fig. 15)

(a) Cotyledons of large seeds bored and eaten (7): larvae of Bean Seed Fly (Corn Seed Maggot in the USA) (*Delia platura*) bore into cotyledons, epicotyl and hypocotyl and prevent germination; similar damage done by small species of slugs.

(b) Seeds dug up and eaten: various species of birds (sparrows etc.) and mice.

(c) Cereal seedling stem with 'dead-heart' (1, 2): maggots of various Diptera (Agromyzidae, Anthomyiidae, Muscidae, Opomyzidae, Chloropidae, and Oscinellidae) bore into the young stem, usually killing the growing point and making the apical leaf turn brown and die; some caterpillars (Crambidae, Pyralidae and Noctuidae) also bore seedling stems of graminaceous plants, but typically they attack older plants.

(d) Stem bored, usually swollen (3): several species of Agromyzidae (Diptera) have larvae that bore in the stem of various seedlings, best known is probably the Bean Fly (*Ophiomyia phaseoli*) widespread and abundant on legumes, it will also bore into leaf petioles on beans.

(e) Stem severed with shoot lying alongside (7): typical cutworm (Noctuidae) and cricket (Orthoptera: Gryllidae) damage; often several consecutive seedlings are cut through; with crickets the cut plant is left for a day to wither and the next night is pulled down into the nest; such damage may be done by surface slugs.

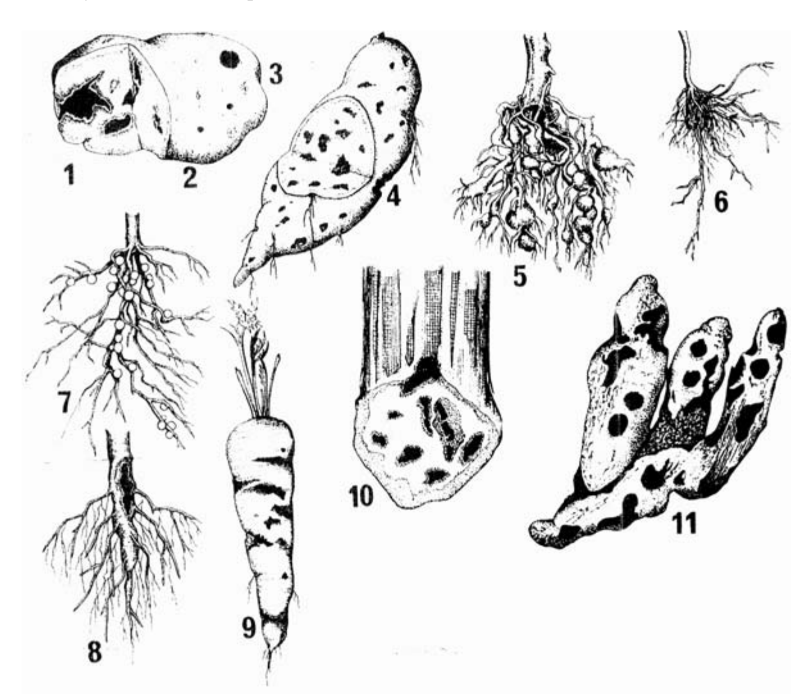
(f) Stem severed and plant removed: several species of termites; can also be done by some leaf-cutting ants and harvester ants.

(g) Stem gnawed at about ground level (2) or below ground: a few beetles belonging to small families, and a few adult scarabs.

(h) Cotyledons or first leaves pitted and eaten: adult flea beetles (Halticinae) make a shot-hole effect on seedlings of Cruciferae, cotton, and other crops, frequently stunting and killing the seedling.

(i) Seedling or young plant wilting and dying (5) as a result of the underground stem being eaten: typical

Fig. 14. Damaged roots and tubers.
1. Potato tuber with extensive, wide tunnelling (Potato tuber Moth larvae (*Phthorimaea operculella*): Lepidoptera; Gelechiidae).
2. Potato tuber with small entrance tunnels (wireworms: Coleoptera; Elateridae).
3. Potato tuber with wide, sometimes shallow, hole (cutworms: Lepidoptera; Noctuidae. Chafer grubs: Coleoptera; Scarabaeidae. Slugs: Mollusca; Limacidae, etc.).
4. Sweet potato tuber tunnelled (larvae and adults of Sweet Potato Weevils (*Cylas* spp.): Coleoptera; Apionidae).
5. Roots with extensive swellings (larvae of some weevils: Coleoptera; Curculionidae. Root Knot Eelworms (*Meloidogyne* spp.): Nematoda).
6. Roots stunted and bushy (Citrus Root Nematode (*Tylenchulus* spp.).
7. Roots with small round cysts (Root Cyst Eelworms (*Heterodera* spp.): Nematoda).
8. Tap root eaten or hollowed (cutworms: Lepidoptera; Noctuidae. Chater grubs: Coleoptera; Scarabaeidae).
9. Carrot root tunnelled (Carrot Fly larvae (*Psila rosae*): Diptera; Psilidae). Other roots tunnelled (root fly larvae: Diptera; Anthomyiidae).
10. Banana rhizome bored (larvae and adults of Banana Weevils (*Cosmopolites* spp.): Coleoptera; Curculionidae).
11. Yam tubers bored (larvae of yam beetles: Coleoptera; Scarabaeidae).



damage by temperate Cabbage Root Fly (*Delia radicum*), cutworms, and African Black Maize Beetles (*Heteronychus* spp.) on maize and sugarcane seedlings (2).

(j) Woody seedling or young plant wilting, with earth-tube up part of the stem; under the tube the bark is eaten away by termites (tropical), or ants.

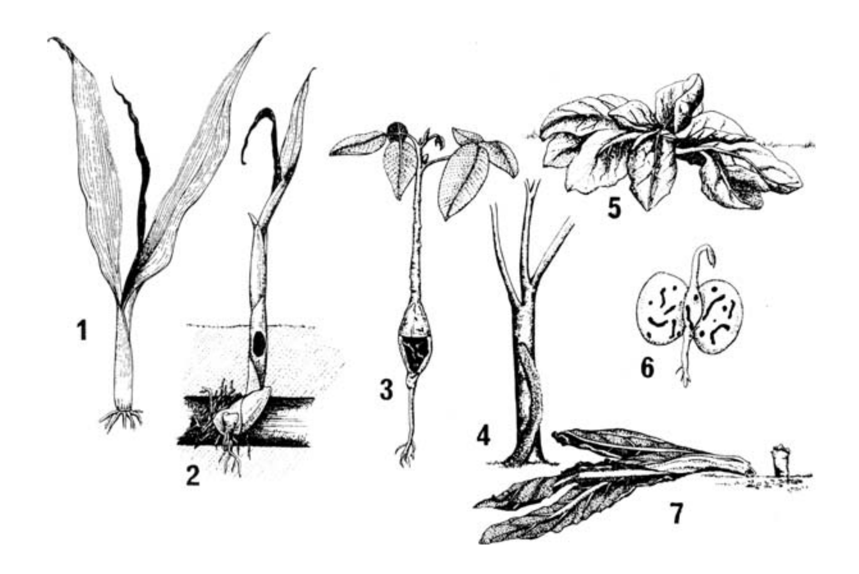
(k) Seedling with hypocotyl gnawed at about, or below, ground level (4): by adult Pygmy Mangold Beetle, symphylids, wireworms (*Agriotes* etc.), and some other soil pests.

Damage to stored products

Damage to stored grains, seeds, and foodstuffs is of particular importance in that it occurs post-harvest, and in theory should be easy to prevent. On-farm storage is usually practised for a while after harvest, particularly on smaller farms, although this is more typical of the tropical parts of the world. In temperate regions it is becoming more usual for communal or commercial harvesting with immediate removal of produce to bulk stores or to market. After a possible period of on-farm storage, the produce is usually taken to a local or regional depot or silo, depending upon the type of crop. Once the produce is taken into warehouses and stores in the cities and towns it is no longer the purview of the agricultural entomologists, but usually the public health inspectorate.

In some parts of the world it is general practice to store root crops (potatoes especially, but also beets, carrots, parsnips, mangels, etc.) in earthen clamps at the edges of fields where they are covered with straw and earthed over to protect them from frost. However, it is now becoming more usual to keep roots and fruits overwinter in large cold stores sited strategically around the country. Stored potatoes and apples clearly have their own special pest problems, such as

Fig. 15. Damage to sown seeds and seedlings.
1. Cereal or grass with 'dead-heart' (larvae of shoot flies, grass flies, etc.: Diptera; Muscidae, Anthomyiidae, Opomyzidae, Chloropidae, etc.). Sometimes young caterpillars of lepidopterous stalk borers.
2. Sugarcane or cereal seedling with stem eaten below ground level (adult Black Maize Beetles (*Heteronychus* spp.): Coleoptera; Scarabaeidae).
3. Legume seedling with swollen hollowed stem (larvae of Bean Fly (*Ophiomyia phaseoli*): Diptera; Agromyzidae).
4. Earth tube up side of woody stem, and young plant wilting; woody stem eaten away under earth tube (termites: Isoptera or ants).
5. Whole seedling or young plant wilting and dying; root/stem eaten (larvae of root fly: Diptera; Anthomyiidae. Cut-worms: Lepidoptera; Noctuidae. Chafer grubs: Coleoptera; Scarabaeidae).
6. Seed cotyledons bored and tunnelled (larvae of Bean Seed Fly (*Delia platura*): Diptera; Anthomyiidae).
7. Seedling stem severed and wilting plant lying on ground (cutworms: Lepidoptera; Noctuidae. Adult crickets: Orthoptera; Gryllidae. Adult Surface Weevil (*Tanymecus indicus*): Coleoptera; Curculionidae).



Potato Tuber Moth, aphids, Codling Moth, fruit flies, etc. In the general studies on stored products pests the produce is usually grain, dried pulses, nuts and the like.

Types of pests

The more important pests of stored products are a few moths in the family Pyralidae, a few mites (Acarina) and the rest are beetles belonging to several different families. In practical terms the most serious pests must include the synanthropic rats and mice, but they are excluded from the present study. On the basis of their feeding behaviour the pests can be categorized as follows.

(a) **Primary pests**: These insects are able to penetrate the intact test of grains and seeds, and include *Trogoderma*, *Sitophilus*, *Rhizopertha*, *Cryptolestes* and *Ephestia* spp.

(b) **Secondary pests**: These are only able to feed on grains already damaged by either primary pests or physically damaged during harvest; such as *Oryzaephilus* spp.

(c) **Fungus feeders**: A number of insects that are regularly found in infested stored products are actually feeding on the fungi growing on the moist produce; but a few species may be both fungus feeders and secondary pests, such as some Psocoptera.

(d) **Scavengers**: These are polyphagous, often omnivorous, casual or visiting pests (as distinct from the resident or permanent pests), such as cockroaches, crickets, some beetles, ants, etc.

Types of damage

(a) **Direct damage**: This is the most obvious and typical form of damage recorded, often measured as a direct weight loss or reduction in volume. But this is not accurate as there is an accumulation of frass, faecal matter, dead bodies, etc. All the insects and the rodents are responsible for such damage. In some flour mite infestations observed the final bulk of exuviae, faeces and dried dead bodies amounted to nearly 50% of the original food volume.

(b) **Selective eating**: Some insects show preference for the germ region of seeds and grains; thus a fairly low level of damage will severely impair germination of stored seeds, and in food grains there will be a serious loss of quality. This preference is shown by *Cryptolestes* and *Ephestia* larvae.

(c) **Heating of bulk grain**: Stagnant air becomes heated by insect metabolism and 'hot-spots' develop. The

moisture from the insects' bodies condenses on the cool grains at the edge of the hot-spot, and the water causes caking, leads to fungal development, and may also cause some grains to germinate.

(d) **Webbing by moth larvae**: The pyralid larvae in stored products all produce silk-webbing, which if present in large quantities may clog machinery and otherwise be a nuisance.

(e) **Contamination**: The presence of insects in the produce, and dead bodies, exuviae, frass, faeces, etc., causes a general loss of quality and value; aesthetic rejection of produce becomes even more pronounced when prepacked in transparent wrappings for supermarket sale.

Cross-infestation

Possibly the single largest problem in produce storage is that of cross-infestation. It generally happens in two ways: firstly, the clean produce is brought into a store that is 'dirty' (i.e. already infested with insects and mites present in cracks and crevices and in rubbish and spilled grain). Secondly, the clean store containing uninfested produce receives a consignment of infested produce and the insects then spread into the previously uninfested material.

Some of the major regional produce stores in some countries, as well as many on-farm stores, are actually never properly 'clean', and in some stores the total pest spectrum in a miscellany of produce may be quite enormous.

Regular inspection

Stored grain should be inspected, and spear samples taken, weekly if insect attack is not to go unnoticed. In some stores ultra-violet light traps and pheromone traps are used for monitoring moth and some beetle populations. With practice trap catches can be correlated with insect populations in the stored produce. For bulk storage regular temperature monitoring is also required.

Reduction of damage to stored products

For the different ways in which damage to stored products may be minimized, and for pesticide application recommendations, see p. 291.

6 *Biological control of crop pests*

The initial enthusiasm with which the first modern insecticides, the chlorinated hydrocarbons, were greeted in the late 1940s and early 1950s has long since begun to wane. This is, in part, the result of the development of resistance by so many pests to many of the pesticides, and also because of the growing awareness of the dangers involved in a gradual poisoning of the whole environment. One result is that many governments have now introduced legislation designed to curb indiscriminate use of the more toxic and persistent insecticides (mostly chlorinated hydrocarbons) and indeed to prohibit the use of the most dangerous pesticides. Another result of this awareness is the acknowledgement of the desirability of trying to control pests by use of cultural or biological means. The single most promising aspect of cultural control is the development and use of resistant varieties of crops. In some texts this is regarded as a biological method of control, but this view is not generally held, since whilst it involves the reactions of living organisms, it is normally regarded as a distinct branch of agricultural science.

The main advantages of biological control lie in:

(a) the absence of toxic effects;
(b) no development of resistance by the pests;
(c) no residues of poison in the soils and rivers, etc;
(d) no build-up of toxins in food chains;
(e) no killing of pollinators, or development of secondary pests through the destruction of their natural enemies;
(f) the permanence of successful biological control programmes where repeated application of chemicals would be required;
(g) the fact that biological control is self-adjusting and does not require the careful timing and organization which should be given to pesticide applications, and which often make it impracticable on small peasant holdings in underdeveloped areas.

Quite often natural control is effective for many pest populations most of the time, but when a population outbreak does occur and methods of control are required, care should be taken so that the *disturbance of natural control factors should be kept to a minimum*. Some of the ways in which this can be attained are:

(a) prediction of pest outbreaks so that insecticidal control can be well planned in advance and used only when necessary;
(b) use of selective insecticides – the more specific the insecticide the less damage it is likely to do to natural control;
(c) by avoiding 'blanket' treatments with insecticides as an insurance measure;
(d) the use of cultural or biological control measures wherever possible;
(e) the encouragement of the increase of natural enemies of the pest;
(f) the growing of pest-resistant crops where possible.

In this chapter biological control (BC) is viewed in the strict sense as the control (lowering) of pest populations by predators, parasites and disease-causing pathogens.

Natural control

First and foremost it must be stressed that it is not possible to overemphasize the importance of the natural control of insect populations. Under natural conditions most insect populations are regulated by a complex of predators, parasites and pathogens causing diseases, all sharing the same habitat and belonging to the same ecological community. This population regulation is sometimes referred to as the *balance of nature* or *natural control*. Under agricultural systems of extensive monoculture, conditions are created that may induce a pest population explosion, but often it is found that the natural enemies increase correspondingly, and so natural mortality rates for the pest remain high and the final pest population does not become very large after all. This is particularly true for perennial orchard and plantation crops, which are present for a long enough time to allow some stabilization of insect and mite populations. The time factor is critical in that parasite populations always lag behind the host populations in their rate of growth (increase), and a fairly lengthy time is required to reach community stability (that is some measure of pest population control). With annual crops, such as vegetables, cereals and cotton, there is generally insufficient time available for specific predator or parasite populations to build up to a level where they can exert any controlling effect, although non-specific (polyphagous) predators and parasites may be important in such situations. The spectacular control of greenhouse pests (red spider mites and whiteflies) by introduced predators and parasites on cucumbers and tomatoes in the UK, northern Europe and the USA is attributable to the greenhouses being very small (in effect tropical) and completely enclosed agroecosystems, and an unnaturally high predator or parasite population is introduced at the start of the control programme. However, although the natural enemies of pests on annual and short-lived crops may seldom completely control the pest populations, their controlling effect is always important. Many crop pests have spectacular fecundity; for example, some female noctuid moths (especially cutworms) lay as many as 2000 eggs per season, and the only reason that the world is not inundated with caterpillars is the high rate of natural mortality due largely to predators, parasites and disease. In temperate regions the fecundity of viviparous and parthenogenetic aphids is almost unbelievable!

Since natural control is present in all pest ecosystems at all times, it is difficult to appreciate the actual extent of its population-controlling effect as it is usually not really noticed until it breaks down. Indiscriminate use of highly toxic, non-specific, persistent pesticides has often resulted in the death of more natural enemies than crop pests. In point of fact, this is now the normal situation with most orchard infestations of scale insects (Coccoidea), in that the mature scales are notoriously difficult to kill with insecticides but the complex of tiny parasitic chalcid and braconid wasps are far more susceptible to the poisons. In these situations pesticide application (with chemicals such as DDT and dieldrin) is almost invariably followed by a population outbreak of the pest. Examples of this phenomenon are now legion!

A nice example of recognized natural control was recorded in northern Thailand where *Patanga succincta* is a serious maize pest; careful field studies revealed that the egg-pods in the soil were heavily parasitized by a scelionid wasp and preyed upon by *Mylabris* beetle larvae; insecticide spraying was carefully restricted to avoid disruption of this natural control. At the same time ducks were introduced into the fields and ate vast numbers of the nymphs, and local villagers were employed to walk through the crops and hand-collect the adults (most of which were later cooked and eaten!). This was a case of partial natural control supplemented by judicious biological control (*sensu stricta*), and with a minimal pesticide application a very high level of overall control was achieved.

Biological control

This is the deliberate introduction of predators, parasites, and/or pathogens into the pest/crop agroecosystem, and is designed to reduce the pest population to a level at which damage is not serious.

Two schematic representations of a pest population being controlled (economically) by natural enemies are shown (from Smith & van den Bosch in Kilgore & Doutt, 1967) in figs. 26 and 27.

The advantages of biological control are several, and have already been listed (see page 48). The predators and parasites may be local species whose natural population is being augmented by the introduction, or they may be exotic species from another country. The most successful examples of biological control are elegant in all respects, but unfortunately most pest situations are not amenable to this method of control. Suitable situations are more likely to be found in the tropics (and sub-tropics) where the climatic conditions favour continuous breeding of insect populations. To date, there are in the region of 200–300 cases of clear success of biological control (*sensustricta*) that are well documented. The original work in this field was carried out in the USA in the early part of this century, mostly in California and Hawaii, to find means of controlling pests of introduced exotic fruits (*Citrus*, etc.). At the present time most work is being done by the various stations of the Commonwealth Institute of Biological Control (CIBC), which are situated in Africa, India, Pakistan, Switzerland, the W. Indies, and S. America. This is one of the institutes belonging to the Commonwealth Agricultural Bureaux, and is a sister institute to the Commonwealth Institute of Entomology International, London.

As already stated, most of the best examples of biological control are from the tropics, but there are many very nice examples from the sub-tropical regions of Florida and California in the USA, and from South China and the Mediterranean Region, all of which lie just to the north of the Tropic of Cancer, and some from Australia and New Zealand. In the cooler temperate regions of Canada, northern USA and northern Europe (including the UK) there is extensive biological control practised, but it is mostly confined to

Fig. 26. Complete biological control (based on the economic criterion) of a pest by an introduced natural enemy. Note that it is not the economic threshold of the pest that is affected by the parasite, but rather its equilibrium position (e.g. long-term mean density) (after Smith & van den Bosch, 1967).

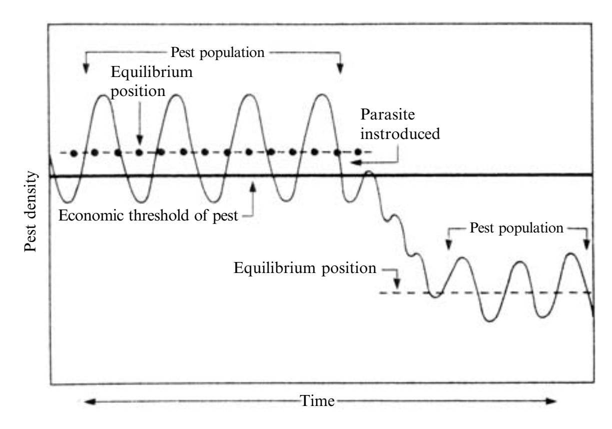
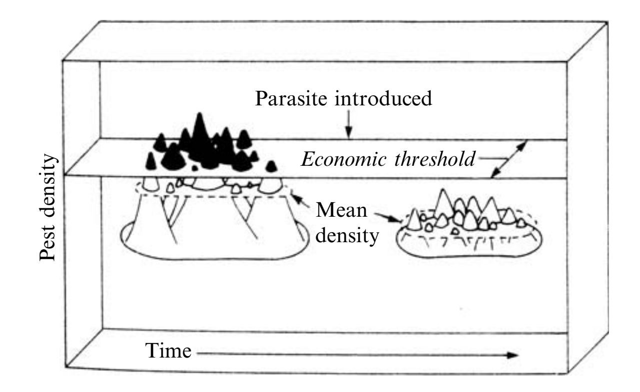


Fig. 27. Three-dimensional representation of biological control of a pest species by an introduced natural enemy. The two populations depict the distributional status of the pest species and its density at particular points in time before and after parasite introduction (after Smith & van den Bosch, in Kilgore & Doutt, 1967).



greenhouses and protected crops, although some forest defoliators have been controlled.

Most crops are indigenous to one particular region of the world, and have been widely transported by man to other regions with a suitable climate in relatively recent times. These exotic crops in their new locations may be attacked by indigenous insect pests quick to seize upon a new food source. Alternatively, their own pests may have either accompanied the crops or else followed soon after, and in the new situation their usual complement of natural enemies is absent, thus permitting a rapid population build-up. The local predators, parasites and pathogens will inevitably be in a state of delicate balance in their own environment and usually cannot be expected to exercise much control over the introduced pests.

The most successful cases of biological control are usually where the predator or parasite has been brought from the area of origin of the crop. For example, the most successful citrus scale parasites have all come from S. China where *Citrus* is indigenous. Usually specific parasites are more successful in stable habitats such as long-established orchards. If the habitat is unstable (as with many agricultural crops) then more general parasites are better suited for control as they can better survive the periods when the specific pest host is absent (between crops). An interesting case is recorded from Japan; here the rice stem borers are controlled partially by the use of *Trichogramma* spp. to parasitize the eggs. After harvest, when there are no more lepidopterous egg masses available, the wasps parasitize the eggs of flies of the genus *Sepedon* (Diptera: Sciomyzidae) in the weedy, fallow lands around the paddy fields, and so the parasite population is maintained (in a state of diapause) over winter. The fly larvae prey on aquatic snails of the genus *Lymnaea* and as such are normally part of the fauna of oriental rice paddy fields.

There is now an extensive literature dealing with biological control, in all its aspects including methodology, history, and giving many examples of successful and unsuccessful cases. The major publications include DeBach (1974), Delucchi (1976), Greathead (1971), Wilson (1960), and the various *Technical Bulletins* and *Reports* published by CIBC.

The information here presented is intended as a summary, including the more important points, such as basic principles, and with a few selected examples. In table 1 is listed some of the more successful biological control projects that have been carried out in temperate situations.

Table 1: *Some successful biological control projects (worldwide).*

Pest	Crop	Predator or parasite	Country	Date	Estimated annual value (US $)
Mythimna separata (Noctuidae)	Maize	*Apanteles ruficrus* (Hym., Braconidae)	New Zealand	1973–5	US $5 mill.
Phthorimaea operculella	Potato	*Apanteles subandrinus*	Zambia	1968	US $70000
Chrysomphalus ficus	Citrus	*Aphytis holoxanthus* (Hym., Aphelinidae)	Israel	1965–7	US $1 mill.
Pseudococcus citriculus	Citrus	*Clausenia purpurea* (Hym., Encyrtidae)	Israel	1940	(Many)
Eriosoma lanigerum	Apple	*Aphelinus mali* (Hym., Aphelinidae)	Australia	1923–36	(Many)
Saissetia oleae	Fruit trees	Various Chalcidoidea	Australia	1898–1905	(Many)
Operophtera brumata	Deciduous trees	*Cyzenis albicans* (Dipt., Tachinidae) *Agrypon flaveolatum* (Hym., Ichneumonidae)	Canada	1955–60	US $2 mill.
Chromaphis juglandicola	Walnut	*Trioxys pallidus* (Hym., Braconidae)	USA (California)	1959 & 1968	(Many)
		Regular biological control practices in temperate greenhouses			
Trialurodes vaporariorum	Glasshouse crops	*Encarsia formosa* (Hym., Aphelinidae)	UK, Europe, N. America, Asia, etc.	1930–	
Tetranychus urticae	Glasshouse crops	*Phytoseiulus persimilis* (Acarina, Phytoseiidae)	Europe, etc.	1960–	
Myzus persicae	Glasshouse crops	*Aphidius matricariae* (Hym., Braconidae)	UK, etc.	1970–	

See also table 3, for some of the B–C agents commercially available now, all of which are obviously economically successful.

There is an interesting history of biological control practices against crop pests in China, indeed the use of some predacious insects in fruit orchards go back to the earliest recorded times. Much of this information has not previously been published internationally, and so in table 2 is listed a selection of the more successful biological control projects carried out in the cooler parts of China; these data were kindly made available by Dr Li, Li-ying in 1980.

Cost of a biological control programme

The cost of a successful introduction, giving long-term control, may be relatively low in comparison with most chemical applications, and very low in relation to the annual saving in terms of losses avoided. For example, DeBach (1964) estimated that the Department of Biological Control, University of California, over a period 1923–59 spent a total of US $3.6 million with a resulting annual saving in California of about US$100 million. A recent case by CIBC, Pakistan, was the establishment of *Apanteles ruficrus* (Hym., Braconidae) against the maize pest *Mythimna separata* (also attacking vegetables and other crops) in New Zealand in 1973–5. The cost of supplying the parasites from Pakistan was US$1700 and the costs involved in New Zealand amounted to about US$20 000; the annual saving is estimated at about US$5 million, with the control still being successful. One oddity noticed was that only the Pakistan strain of parasite was particularly effective.

A similar case was the control of Winter Moth (*Operophtera brumata*) in Canada. It was accidentally introduced into Nova Scotia in the 1930s, but first noticed in 1949; it eventually increased in numbers and spread inland and the damage to deciduous hardwoods (mostly oak, but this is a polyphagous pest) soon reached economic proportions. Parasites from Europe were imported and effectively colonized over the period 1955–60 (see table 1) bringing the Winter Moth under complete population control. The overall total cost of

Table 2: *Biological control of some insect pests in China* (Li, Li-ying, 1980; *in litt*.)

Pest	Crop	Predator, parasite or pathogen	Date	Locality	Success
1. *Pseudococcus* spp.	Tung	*Cryptolaemus montrouzieri* (Col., Coccinellidae)	1955–1979	Guangdong	Yes
2. *Aphis* spp.	Cotton, Wheat, etc.	*Coccinella septempunctata* (Col., Coccinellidae)	1971–	Henan	Yes
3. *Heliothis armigera*	Cotton	*Trichogramma* spp. (3)	1970–	Hubei, Shangsi	Yes
4. Corn borers	Maize	*Trichogramma* spp. (3)	1970–	N. China	Yes
5. *Grapholitha glycinivorella*	Soybean	*Trichogramma* spp. (3)	1970–	N. China	Yes
6. *Eriosoma lanigerum*	Apple	*Aphelinus mali* (Hym., Aphelinidae)	1955	Shangdon	Yes
7. *Pieris brassicae*	Cabbages	*Pteromalus puparum* (Hym., Pteromalidae)	1974–	Anhui, Guangdong	Yes
8. Cotton pest complex	Cotton	*Vespa, Polistes* spp. (Hym., Vespidae)	1975–	Henan, Jiansu	In progress
9. Various borers	Sugarcane	*Tetramorium guineense* (Hym., Myrmecinae)	1961–	Guangdong, Fujian	Yes
10. Various pests	Cotton	*Chrysopa* spp. (Neuroptera, Chrysopidae)	1975	Henan	Limited
11. *Panonychus citri*	Citrus	{ *Amblyseius newsami* *Typhlodromus pyri* (Acarina, Phytoseiidae)	1975– 1975–	Guangdong Sichuan	Yes Yes
12. Various pests	Rice, Cotton	{ Various Argiopidae, Lycosidae, Tetragnathidae, Micryphantidae, Clubionidae, etc. (Arachnida, Araneida)	1975–	Hunan, Zhejiang	Yes
13. Corn borers *Grapholitha glycinivorella*	Maize Soybean }	*Beauveria bassiana* (fungi)	1965–	most provinces of China	Yes Yes
14. *Trialeurodes vaporariorum*	Greenhouse vegetables	*Encarsia formosa* (Hym., Aphelinidae)	1979–	Beijing	In progress
15. Lepidopterous pests	Vegetables, rice, cotton	*Bacillus thuringiensis*	1970–	Most provinces of China	Yes

the project was estimated at about $160 000 and the annual saving to the hardwood industry was estimated at $2 million.

These levels of cost in relation to savings are typical of the more spectacular biological control successes, but the less-successful projects are still quite inexpensive and the whole problem of pesticide residues and side-effects is avoided. The control of glasshouse pests using predators and parasites compares favourably with the use of chemicals, and there are no toxicity hazards.

Commercial availability of biological control agents

In the last few years many commercial establishments have been incorporated and they breed and supply predators, parasites and pathogens to commercial growers and farmers. The pioneer work in this field was usually carried out on Government research stations, the various CIBC stations throughout the world, and other autonomous establishments, such as GCRI in the UK. But now bulk production is in the hands of commercial companies.

Most of the predators tend to be non-specific and so may be used against a number of different crop pests, or against a particular pest complex. Lacewings, ladybird beetles, wasps and spiders belong in this category.

The parasites are usually quite specific, but they sometimes accept hosts belonging to the same family, so some *Trichogramma* species will parasitize a wide range of lepidopterous eggs, and *Nasonia* (Hym., Pteromalidae) will accept the pupae of many different Muscoidea. It is more usual though for the parasites (Hymenoptera and Tachinidae) to be quite host specific.

Some of the biological control agents currently available from commercial suppliers in temperate regions are listed in table 3. However, it must be stressed that the situation differs in each country and so the local Ministry of Agriculture staff should be consulted for local information.

Fortuitous biological control

It should perhaps be mentioned, as pointed out by DeBach (1971), that there has been considerable, unrecognized, fortuitous biological control resulting from ecesis (accidental dispersal and establishment) of natural enemies throughout the world. This is particularly the case with some scales (especially Diaspididae) and their parasites, because the scales are tiny, sessile, inconspicuous (especially in low numbers) and easily transported on either fruits or planting material (shoots and rootstocks). DeBach uses the specific parasite, *Aphytis lepidosaphes*, of the Purple Scale (*Lepidosaphes beckii*) as a good example. Purple Scale is indigenous to the area of S. China and Indo-China, and it is highly specific to *Citrus*. During the past 100 years or so Purple Scale has gradually (accidentally) spread and invaded most of the major *Citrus*-growing areas of the world, from the Mediterranean to S. Africa, Australia, N., C. and S. America, and the W. Indies. DeBach records that *Aphytis lepidosaphes* (first discovered in China in 1949) is slowly spreading around the world, although the only deliberate introduction was into California in 1949; apparently, at that time it was (as discovered later) already established in Hawaii, presumably as a result of an earlier accidental introduction. The most recent colonizations by this specific parasite include Spain (1969) and Argentina (1970). In almost every country checked by DeBach, *Aphytis lepidosaphes* is responsible for substantial to complete biological control of Purple Scale on *Citrus*.

Predators

The importance of insect pest predators is now being reassessed in many countries because of their obvious value in IPM programmes.

The value of wild birds as insect predators is clearly demonstrated in urban situations, where tits (Paridae) and sparrows (Ploceidae) can be seen searching fruit trees, roses, etc., for aphids, caterpillars, and other insects, and thrushes (Turdidae) eat large numbers of slugs and snails. Domesticated birds are being used to control insects in parts of the tropics very successfully. For many years peasant farmers in Africa have been using chickens on their shambas in cotton plots to eat the cotton stainers and other bugs that drop to the ground (as an escape mechanism) when disturbed. About 40 chickens per acre is the accepted number of birds required for adequate control. Recently in S. China (and other parts of India and S.E. Asia) effective use of ducks has been made against rice pests. In Guangdong on the early rice crop, after transplanting and establishment of the plants, 220000 ducklings (about half-grown) were herded slowly through the paddy fields. Each duckling was estimated to eat about 200 insects per hour, and most of these were inevitably pests. The overall effect of this predation was that the amount of chemical insecticides required on the early rice crop was reduced from 77000 kg in 1973 to 6700 kg in 1975. Following this early success, ducks are now being used as rice pest predators in many parts of the Far East. In Thailand, in 1980, adult ducks were used successfully to eat adults and large nymphs of the Bombay Locust (*Patanga succincta*) that had been enticed out of the upland maize crop into intercropped soybean foliage and also groundnuts. In this case ducklings would have been useless as the locusts were too large for them to kill. At the same time local villagers were paid to hand-collect adult locusts, and in a few days 80 tons were collected; the locusts were later either roasted and eaten by the villagers or made into a paste for culinary purposes. (There are times when man can be a direct insect predator of some consequence!)

Within the Vertebrata one amphibian has been used a few times for biological control of insects; this is the giant toad (*Bufo marinus*), which was introduced into Hawaii in 1932–3 in an attempt to control various beetles (Scarabaeidae) attacking sugarcane, and was released in Australia (Queensland) in 1935–6. It is now flourishing in both locations where it generally seems to cause more ecological disturbance than benefit; this is in part because it eats small vertebrates as well as insects, and the toads are poisonous if eaten by other vertebrates.

Table 3: *Some of the biological control agents commercially available in the UK, Europe, and N. America.*

Predators Organism	Description	Against	Supplied as:
Chrysopa spp.	Lacewings (Neuroptera)	General predators	Larvae or pupae
Cryptolaemus spp.	Ladybird beetles (Col., Coccinellidae)	Mealybugs, etc.	Active adults
Amblyseius spp. }	Predacious mites	Thrips, etc.	Active mites
Phytoseiulus persimilis }	(Acarina, Phytoseiidae)	Red Spider Mites	Active mites
Parasites			
Trichogramma spp.	Egg parasites (Hym., Trichogrammatidae)	Lepidoptera	Pupae in parasitized eggs
Encarsia formosa	Nymphal parasite (Hym., Aphelinidae)	Glasshouse Whitefly	Pupae in parasitized 'scales'
Diglyphus isaea	(Hym., Eulophidae)	Chrysanthemum–Tomato	Active adults
Dacnusa sibirica/Opius pallipes	(Hym., Braconidae)	Leaf Miners	Active adults, or parasitized pupae
Aphidius matricariae	(Hym., Braconidae)	*Myzus persicae*	Parasitized aphid mummies
Micro-organisms			
Bacillus thuringiensis	Bacterium	Caterpillars	Suspension
Bacillus spp.	Bacteria	Beetle larvae	Suspension
Verticillium lecanii	Fungus	Aphids Glasshouse Whitefly	Spore suspension as a w.p.
Beauveria bassiana	Fungus	Caterpillars	
Granulosis viruses/nuclear polyhedrosis viruses	Viruses	Caterpillars & some beetle larvae, sawflies	Viral bodies in a w.p.

A few of the best-known suppliers of biological control agents are listed below:

UK

Applied Horticulture Ltd., Billinghurst, Sussex
Bunting & Sons, Colchester, Essex
Natural Pest Control, Bognor Regis, W. Sussex

(It must be stressed that these are just a few of the companies concerned, and now a large number of companies worldwide are producing b–c agents.)

USA

Fairfax Biological Labs.
Nutrilite Products Inc.
Biological Control Supplies
Rincon–Vitova Insectaries Inc., California
International Minerals Chemical Corp.

It should perhaps be mentioned that the main reason for the tremendous upsurge of rats (*Rattus* spp.) as urban and agricultural crop pests in India and throughout S.E. Asia is largely due to the destruction of their main predators which are snakes, especially the venomous cobra (*Naja naja*; Elapidae), and the non-venomous, but fanged and aggressive, rat snakes (*Ptyas* spp., *Elaphe* spp., etc., Colubridae). For inexplicable reasons most peasants and farmers in Africa and tropical Asia have a morbid dread of all snakes, most lizards, and salamanders, being convinced that they are all highly venomous and lethal. The consequence is, regrettably, the wholesale and widespread destruction of local snake populations, with a subsequent population explosion of suburban rats. The situation is somewhat aggravated in S.E. Asia as it is the endemic source of the frugivorous arboreal *Rattus rattus* subspecies group. It is estimated by FAO that in India there are five rats per person, and that in recent years 10% of the grain harvests have been lost due to rat attack. In S.E. Asia the main pests of oil palm (and in some areas coconut) are rats; in the Philippines the crops damaged also include sugarcane and maize.

It has long been obvious that spiders were an important part of the natural control community throughout the world, but only recently have they been studied in this role. Work at IRRI in the Philippines and in S. China has shown that many rice pests (especially Cicadellidae and Delphacidae) are heavily predated by spiders. In some experiments mortality rates of the Brown Planthopper of Rice reached 70% due almost entirely to spider predation. In parts of China (Hunan, Zhejiang), since 1975, spiders belonging to more than five different families have been reared and released on rice and

cotton crops, against a broad range of insect pests, with considerable success (Li, Li-ying, *in litt*., see table 2). Both the web-spinning and the webless wolf spiders have been used. A recent publication on spiders as biological control agents is by Riechert & Lockley (1984). At IRRI it was discovered that γ-BHC was particularly toxic to spiders, both directly by contact and indirectly by their eating poisoned prey; obviously such insecticides should be avoided in any IPM programme where spiders are important natural predators.

Also in the class Arachnida are the mites (order Acarina). In the same way that insects are heavily preyed upon by other insects, the major predators of phytophagous mites are carnivorous mites, most of which belong to the family Phytoseiidae. The three main genera used in biological control programmes are *Phytoseiulus*, *Amblyseius*, and *Typhlodromus*. The original widespread use of these predatory mites against spider mites (Tetranychidae) was in greenhouses in the UK and the USA (on cucurbits, tomatoes, etc.) with spectacular success. Later it was realized that on field and orchard crops in warmer regions they could also be successful. Various companies now provide commercial sale of phytoseiid mites for biological control purposes.

Predacious insects are important population controlling factors for many insect pests, but their precise roles in natural control have seldom been evaluated and documented. It was, however, reported from the Solomon Islands that, in 1975 and 1976, the Brown Planthopper of Rice was not a pest on rice (economic pest, that is) because of good control by a predacious mirid bug (*Cyrtorhinus*). Many members of the Miridae, Anthocoridae, Reduviidae, Pentatomidae, and other Heteroptera, are important natural predators. *Orius minutus* has been used in China since 1976 for the control of various cotton pests in Hubei and Jiansu with some success. *Platymeris laevicollis* (Reduviidae) is an important predator of Rhinoceros Beetle adults (*Oryctes* spp.) and has been introduced from Zanzibar into India, Fiji and New Caledonia (Lever, 1969); each adult bug can destroy one adult beetle per day and may live for four months.

In the Diptera there are some Cecidomyiidae that prey on Coccoidea, and there are a number of rather obscure families, in addition to the obvious Asilidae (robber flies), where the adults prey on other insects. But without doubt the most important group is the Syrphidae (hover flies) in which many species have predacious larvae. They feed on aphids, coccids, other small plant bugs and small caterpillars. Being legless, headless and blind it is rather surprising that syrphid larvae are effective predators, but the eggs are laid amidst dense populations of suitable prey so the emerging larvae manage to feed effectively with the aid of their mouthhooks and rather simple sensilla (chemosensory and tactile). Although very important in natural control, Syrphidae are not much used in biological control programmes as their limited powers of searching make them not really suitable. One oddity is that in the UK they have been recorded as a nuisance in commercial pea (*Pisum sativa*) crops; the peaviner also threshes and when the fresh peas (seeds) are removed from the pods and collected in the hopper they are accompanied by the small globular syrphid pupae which were dislodged from the foliage. Customers buying a packet of frozen peas are invariably annoyed to find syrphid pupae enclosed.

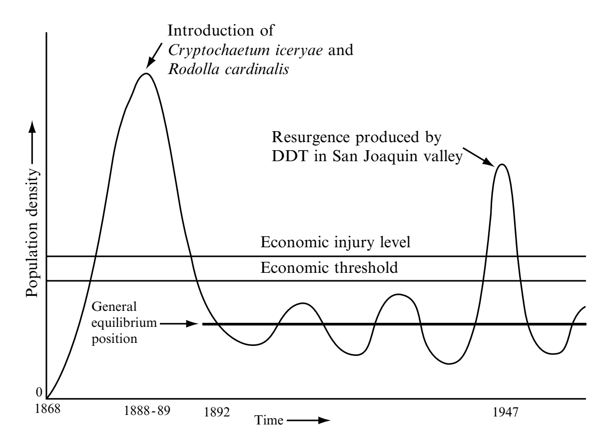
The Hymenoptera have a few predacious groups of importance. The Vespidae, the social wasps, are all carnivorous and feed upon other insects. In most parts of the world *Vespa* and *Polistes* are regarded as pests because they damage ripe fruits, and also they nest in crops and attack the field-workers if disturbed. But in China (and some other countries) they are being used as general predators in cotton crops. Similarly ants (Formicidae) include carnivorous species that will prey on crop pests, and *Oecophylla smaragdina* (Red Tree Ant) is successfully controlling *Rhynchocoris humeralis* on *Citrus* in Guangdong, China; this method has in fact been used in China since ancient times. The African Red Tree Ant (*O. longinoda*), when nesting in a coconut palm, keeps the palm free of Coconut Bug. But these ants sometimes guard bug colonies, and as they are quite aggressive they may attack field-workers. So, like the wasps, (*Vespa* and *Polistes*) it is a moot point whether they are more important as pests or as beneficial predators. Scoliidae prey on beetle larvae, mostly chafer grubs, in the soil, but attempts to use them for the control of *Oryctes* spp. in S.E. Asia have not been very successful.

The Neuroptera as an order are almost entirely predacious, both as adults and larvae, and clearly they are an important group in the natural control of many insect species. Green lacewings (*Chrysopa* spp.) are quite easy to rear, and are now available commercially for biological control use. As general (i.e. non-specific) predators they are useful in IPM programmes, but will only give limited control of any particular pest.

Coleoptera include many important groups of predators. In some families, both adults and larvae are fiercely predacious (e.g. Carabidae, Staphylinidae, Cicindelidae, Histeridae and Coccinellidae), but in others only the larvae are (Hydrophilidae, Meloidae, Lampyridae). The Carabidae include the Indian *Pheropsophus hilaris* which has been successfully used in Mauritius to kill larvae of the Rhinoceros Beetle. Most of the predacious beetles are litter and soil-dwellers and so are mostly used against soil-inhabiting pests, for obvious reasons. The major exception to this is, however, the Coccinellidae (ladybird beetles) which are arboreal foliage dwellers. Apart from *Epilachna*, the entire family are predators and very effective control agents, both as adults and larvae. They are used mainly against aphids and coccoids, and also kill small caterpillars. Ladybirds are easy to rear and can be bought commercially in large numbers from many establishments. Successful examples of their use in biological control are too numerous to list, but a few are included in the tables. Fig. 28 shows the effect of coccinellid predators on *Icerya purchasi* in California in 1868, one of the earliest documented cases of biological control.

The Meloidae are important in the natural control of many locusts and grasshoppers; the triungulin larvae seek

Fig. 28. Schematic graph of the fluctuations in population density of the Cottony Cushion Scale (*Icerya purchasi*) on citrus from the time of its introduction into California in 1868. Following the successful introduction of two of its natural enemies in 1888, this scale was reduced to noneconomic status except for a local resurgence produced by DDT treatments (from Stern *et al.*, 1959).



out and prey upon the egg-pods of Acrididae in the soil, and in parts of the tropics their value is considerable. As already mentioned *Mylabris* larvae exert considerable control pressure on the Bombay Locust in N. Thailand.

Soil insects, especially root maggots (Anthomyiidae) and cutworms, suffer very heavy natural predation by ground beetles (Carabidae) and rove beetles (Staphylinidae). Cabbage Root Fly regularly suffer 90–95% loss of eggs and larvae due to beetle predation (Coaker & Finch, 1970), about two-thirds of the loss being in the egg stage. The most important Carabidae are *Bembidion*, *Ferronia*, *Harpalus* and *Trechus*, all of which are large and abundant genera.

Parasites

The three outstanding groups of insect parasites are the Tachinidae (Diptera), and the Chalcidoidea and Ichneumonoidea (both Hymenoptera). They are vitally important, both in the natural control and biological control of insect crop pests. Within the Diptera are families such as Pipunculidae, Phoridae, Bombylinidae and Sarcophagidae which are of minor importance as natural parasites of insect pests. There are also some anomalous groups like the Sciomyzidae which live in oriental paddy fields and whose eggs provide alternative hosts for *Trichogramma* wasps during the period when stalk borers (*Chilo*, *Tryporyza*, etc.) are absent.

The Tachinidae parasitize a very large range of hosts worldwide, including the larvae of lepidopterans, the larvae and adults of coleopterans, and nymphs and adults of orthopterans and hemipterans.

Ichneumonidae and Braconidae parasitize a wide range of insects, ranging from the wood-boring larvae of Siricidae, to cereal stem borers, aphids and scales. Some species have long ovipositors and are able to parasitize larvae *in situ* in wood or cereal stems. Probably the most important genus is *Apanteles* (Braconidae) with its many species, which parasitize the larvae of Noctuidae and Pyralidae. These species are generally not difficult to rear, and some are bred regularly at various CIBC stations.

The Chalcidoidea includes some 19 families, most of which (excluding the Agaonidae – fig wasps) are parasites of caterpillars, beetle larvae, fly larvae and pupae, and large numbers feed on aphids, scales, mealybugs, psyllids and other Hemiptera. A few species parasitize Orthoptera, spiders, ticks, and other insects. Several groups, especially the Trichogrammatidae, are solely egg parasites and use the eggs of Hemiptera, Lepidoptera, and some Diptera, Orthoptera and others. Species of *Trichogramma* are being widely used in many IPM programmes in different parts of the tropics, and several species are available commercially in the USA. Some species of *Trichogramma* are especially useful in their being polyphagous and parasitizing a range of similar-sized eggs. It should be mentioned that Scelionidae and Proctotrupidae are also important as egg parasites, largely of Lepidoptera; they are Parasitica but not Chalcidoidea. The total complex of parasitic Hymenoptera (including hyperparasites) that can be reared from scale insect and aphid colonies is at times quite bewildering. The most important chalcid families for biological control purposes and their insect hosts are as follows: Chalcididae (pupae of Lepidoptera and Diptera mostly); Pteromalidae (many different insects, some species are polyphagous); Encyrtidae (Coccoidea, also aphids, psyllids, some Diptera, Lepidoptera, Coleoptera; some species are hyperparasites); Eulophidae (eggs, larvae and pupae of many insects); Aphelinidae (Coccoidea, Aleyrodidae, Aphidoidea, some Psyllidae, Cicadoidea and eggs of Orthoptera and Lepidoptera); Trichogrammatidae and Mymaridae (eggs of many different groups).

The Strepsiptera are a small order of the Insecta in which the larvae and adult females are obligatory internal parasites of some bees and Hemiptera, and a few species are regarded as important in the natural control of some heteropteran bugs.

A few species of Nematoda are entomophagous. Species of nematodes, including *Romanomermis culicivorax*, are being used very successfully in controlling populations of mosquito larvae in ponds and swamps. The nematode–bacterium complex of *Neoaplectana carpocapsae* and *Achromobacter nematophilus* (known as strain DD-136 and available commercially as ‘Biotrol NCS’ from Nutrilite Products Inc., USA) appears to be effective against some rice stem borers (larvae and sometimes pupae), for example *Chilo*, *Tryporyza* and *Sesamia*, and seems to be a very promising biotic insecticide for use against many caterpillars and some beetle larvae (such as Colorado Beetle).

In Australia commercial use of two genera of rhabditoid nematodes has recently started (Bedding, 1984) with considerable success. *Neoaplectana bibionis* almost totally eradicated the stem borer *Synanthedon salmachus* from 0.5

million cuttings of blackcurrant used to establish new plantations. *Heterorhabditis heliothidis* is reported as successfully controlling Black Vine Weevil larvae (*Otiorhynchus sulcatus*) in potted plants, and in strawberry plantations. And *Neoaplectana feltiae* (= *carpocapsae*) is said to control the carpenterworm, *Prionoxystus robinae*, in trees of *Ficus carica*. In this paper a method of rearing insect-parasitic nematodes on a large scale is described, as also are methods of storage and transport; studies such as this will enable commercial production techniques for nematodes to be refined and costs lowered so that this method of insect pest control may be economically comparable to other present techniques.

A very interesting account, titled *Nematodes with potential for biological control of insects and weeds* was written by Nickle (1981) and published in *Biological control in crop production* (Papavizas, editor). A summary of his comments follows:

Host insects	*Nematode parasites*
Grasshoppers (Orthoptera)	*Mermis* spp.
	Agamermis spp.
Beetles	*Psammomermis* spp.
(Coleoptera: Scarabaeidae)	*Howardula* spp.
(Curculionidae)	*Hexamermis* spp.
Lepidoptera	*Neoaplectana* spp.
	Amphimermis spp.
	Hexamermis spp.
Diptera	*Heterotylenchus* spp.
	Howardula spp.
(Mosquito larvae,	*Romanomermis* spp.
Simulium, *Culicoides*)	*Mermis* spp.
Homoptera (Cicadellidae)	*Agamermis* spp.

In some cases the nematodes did not kill the insect, but sterilized the females so that they lived and spread the parasites but did not breed.

Pathogens

Fungi. Many fungal antibiotics have been in commercial production for use against plant diseases for a long time, and they have generally been quite effective. It is well known that insects (and some mites) regularly suffer epizootics from fungal attack, but it is only in the last decade that the development of entomopathogenic fungi for insect pest control has been seriously contemplated, and now it is evident that the use of fungi for pest control is both feasible and should be profitable in all respects. A paper by Soper & Ward in Papavizas (1981) titled, *Production, formulation, and application of fungi for insect control* presents a summary of work on this topic. It is estimated that there are 750 species of entomopathogenic fungi, but at present only a few are being used to any extent. However it is thought that many more will be developed commercially in the not too distant future, now that the principles of epizootiology are better understood.

It was formerly thought that the fungi were unreliable pathogens in that they were too dependent upon environmental conditions, especially moisture, to be satisfactorily manipulated for pest control. For the past few years a fungus has been used to control greenhouse aphids and whitefly in the UK, very successfully, but this has been in the confines of greenhouses. However, it does appear that fungal control on field crops is likely to be quite feasible.

A few of the more important parasitic fungi are listed below:

Fungus	*Host insect/mite*	*Country*
Aschersonia spp.	Aleyrodidae; scales	USSR
Beauveria bassiana	Colorado Beetle	USSR, USA
(= *globulifera*)	Corn borers	China
	Chinch Bug	USA
Conidiobolus obscurus	Aphids	UK, USA, France
Culicinomyces clavosporus	Mosquitoes	Australia
Entomophaga grylli	Grasshoppers /locusts	USA
Entomophthora musci	Muscoid flies	Europe
Hirsutella thompsoni	Citrus Rust Mite	USA
Lagenidium giganteum	Mosquitoes	USA
Metarhizium anisopliae	Cercopidae	Brazil
	Mosquitoes	USA
	Field crickets	Australia
	Rhinoceros Beetle	S. Pacific, Philippines
Nomuraea rileyi	Caterpillars	USA
Verticilium lecanii	Greenhouse aphids/whitefly	UK
Zoophthora radicans	Spruce Budworm	USA
Zoophthora radicans	Diamond-back Moth	(Asia & UK) (1988)

Other entomophagous fungi recorded in UK greenhouses include *Cephalosporium aphidicola* and *Entomophthora coronata*, and they show some potential for use in control programmes. New Project in UK (Rothamsteol).

Bacteria. There are four species of *Bacillus* that are regarded as being entomophagous, but only the one being produced commercially *in vitro*. The four species are as follows:

Bacterium	Insect host
Bacillus thuringiensis	Caterpillars (Lepidoptera)
B. popilliae	Beetle larvae (Scarabaeidae)
B. moritai	Some caterpillars
B. sphaericus	

B. thuringiensis is now produced commercially *in vitro* and is available under a number of different trade names

in different countries. In this book it is included in chapter 8 as a biological insecticide. This bacterium produces several different toxins which are entomocidal, and it appears to occur as several distinct strains, making it a very complex species. This basic variability may account for some of the variation in results when used to control caterpillars on crops. It is often found to work well in laboratory testing, but to produce very variable results in field trials. The commercial preparations are generally short-lived, and so repeated applications may be necessary. However, with the rapidly developing resistance shown by some caterpillars (especially Diamond-back Moth), BTH is very useful insecticide against cabbage caterpillars, and others, as part of a control programme.

B. popilliae causes Milky Disease and is very effective in controlling Japanese Beetle. It has been shown to be very persistent and to give long-term control, but to date has only been produced *in vivo* in *Popillia japonica* larvae and cannot be produced *in vitro*, which means that commercial production is very limited, although it is marketed in the USA under the trade name 'Doom' by Fairfax Biological Labs.

Three important publications of relevance here are Dulmage in Papavizas (1981) *Production of bacteria for biological control of insects*, Falcon in Huffaker (1971), chapter 15, *Microbial control as a tool in integrated control programmes*, and Ferron (1978) on entomogenous fungi.

Viruses. The two main types of entomophagous viruses are those described as granulosis viruses (including Codling Moth GV, Summer Fruit Tortrix GV and Cabbage White Butterfly GV) and the polyhedrosis viruses. *Heliothis* PHV has already been mentioned as a biological insecticide (page 62) as it is now widely available commercially. Other PHVs include ones specific *Bacculovirus etinnys* on Cassava Hornworm (Brazil) to *Neodiprion* larvae (sawfly), *Trichoplusia* and *Spodoptera/Prodenia* larvae. These latter viruses are still undergoing trials, and at present it is not known if they will become generally available.

A natural PHV occurs on Cotton Semi-looper (*Anomis flava*) in Queensland, Australia, and is an important population-controlling factor; at times the proportion of the looper population which was infected was as high as 50%. It was suggested by Blood & Bishop (1975), as might be expected with an epizootic, that a certain minimum population of larvae (population abundance threshold) is required for a disease outbreak proper, and they calculated from two seasons' data, using regression analysis, that for *A. flava* the population abundance threshold might be about 130000 (± 10000) larvae per hectare before a significant disease outbreak would occur.

A review of recorded cases of insects with virus diseases was published by Hughes (1957).

Protozoa. In the Beltsville symposium published in 1981 (Papavizas, editor) Canning discussed *Insect control with Protozoa*, and stressed that the only groups likely to be of use in pest control were the Coccidia, Neogregarines and Microsporidia. She refers to a model developed to investigate the eradication of pest populations by microbial agents (Anderson & May, 1981); the parasite parameters in the model are pathogenicity, spore survival time, and transmission rate. Microsporidia are seldom quickly lethal, but have higher mortality rates with older larvae and pupae. Spores are not very resistant and seldom survive long in the environment, but some are transmitted transovarially which is highly desirable in a biological control agent.

The effectiveness of a protozoan parasite on insects can be seen by the well-publicized damage done to honey bee colonies by *Nosema apis*. A few of the more notable protozoan insect parasites are listed below:

Protozoan	*Host insect*
Nosema operophterae	Winter Moth (*Operophtera brumata*)
Nosema sp.	
Pleistophora operophterae	
**Nosema locustae*	Grasshoppers/locusts

*recorded effective against 58 spp. - commercially available in bran bait (Noho Bait) = USA.

Biological control failures

In the past many of the biological control failures appear to have resulted from careless handling of the predators and parasites in shipment, together with accidental delays in transit and distribution, and were not due to intrinsic factors in the host/parasite biology. However, simultaneously, many introductions were made without any real scientific basis for the choice of predator or parasite, except perhaps convenience! Thus, there was often little success achieved. For example, the history of biological control attempts in Australia (F. Wilson, 1960) against insect pests reveals a large number of unsuccessful cases, and a similar situation prevailed in Africa (Greathead, 1971; see Hill, 1975 & 1983).

Firstly, the identity of the pest must be clearly established, and the taxonomists need to be made aware of any biological differences, as well as morphological or anatomical differences between various pest species (e.g. *Planococcus kenyae*). Secondly, most serious pests are not indigenous to the area in which they are pests, and so it is necessary to go back to their country of origin for suitable predators and/or parasites for possible introduction (e.g. *Planococcus kenyae*). Thirdly, it is generally a waste of time to introduce parasites or predators which usually attack another genus of pest, even though the two pests may have very similar biologies (e.g. *Scyphophorus*). It must be borne in mind, however, that generally predators are less specific in their choice of prey than are parasites. Parasites of closely related species of pests from different parts of the world may be worthwhile introducing sometimes, but more often parasites are species-specific and will not attack the new host (e.g. *Leucoptera* spp. and *Mirax*). Fourthly, when the pest is indigenous to the area in which it is a nuisance, it is generally not worthwhile to attempt to breed-up large numbers of one of the local

parasites for local release since the usual pest/parasite complex is more often a stable and long-established one which will not permit changes of this nature. Also, if the parasite complex is extensive, there is little chance of being able to successfully insert another species into the complex, even if it comes from another area altogether (e.g. *Leucoptera* spp.), although sometimes this is successful. Generally it is best to find out if there are any predator/parasite niches which are not filled and then attempt to introduce a species that will effectively fill that niche.

Fifthly, when making the original survey of the pest parasite complex, it is vital to do the job thoroughly to make certain that all the local parasites are found. Should an introduction be made of a parasite species which is already present in the area, but not detected owing to careless surveying, then this is likely to have little effect and prove to be a waste of effort (e.g. *Hypothenemus hampei* in Kenya).

One of the problems associated with early attempts at the introduction of parasites from other countries was the time taken for consignments of insects to be shipped from country to country, and many consignments were found to be dead on arrival. Nowadays, with rapid and regular airline services, such consignments of insects can be sent either by air-mail or air freight and arrive at their destination within only a few days.

The facilities required for mass propagation of parasites or predators are not unduly complicated but are generally beyond the scope of most agricultural and entomological research stations. However, in recent years many research stations have become equipped with such facilities. In addition there is the chain of stations and substations of CIBC scattered throughout the world. The result of these developments is that now it is generally possible to obtain suitable predator or parasite species in very large numbers, bred either in the country of origin or in the country of introduction, so that tens or hundreds of thousands of individuals may be released instead of only a few hundred, which was all that was often possible in the past. Clearly the larger the number of individuals that can be released, the greater the chances of the introduction being successful.

As pointed out by F. Wilson (1960), it has been customary to characterize attempts at biological control as either 'successful' or 'unsuccessful'. In reality this oversimplification is undesirable for it is fairly obvious that many different levels of biological control are achieved. For the sake of definition it can be said that a biological control project is 'completely successful' if other forms of control can then be dispensed with. In the oversimplified view the project is regarded as 'unsuccessful' if other methods of control still have to be utilized. This attitude is totally unrealistic; chemical applications normally give many different levels of control, as is only to be expected. Wilson summarizes attempts at biological control of insect pests in Australia by making five categories based on the levels of success achieved:

(a) pests substantially reduced in status;
(b) pests reduced in status;
(c) pests of doubtfully diminished status;
(d) pests of unchanged status;
(e) pests against which the introduced enemies failed to become established.

7 *Pesticide application*

Methods of pesticide application

In the application of pesticides to crop plants, the object is to place the chemical in or on the correct part of the plant in order that it might come into suitable contact with the insect pest. For a leaf-eating insect a pesticide should either be on the leaf surface or in the leaf tissues; for a sapsucker the poison should be in the phloem system. For a leaf-miner the poison must penetrate into the leaf tissues to be effective. A soil-inhabiting, root-eating pest can be attacked either through the tissues of the roots or else by a contact insecticide, introduced into the soil around the roots. Many of the caterpillars (and fly larvae) which in their later instars bore into fruit, or plant stems, hatch from eggs laid on the surface of the plant or on the soil and the first instar larvae spend some time on the plant surface before burrowing into the stem or fruit. Thus, these larvae, which in later instars are almost invulnerable once they are inside plant tissues, can be attached by carefully timed and placed pesticide application. Seedling pests can be attacked by the use of a seed dressing on the sown seed. With a contact insecticide it is imperative that the chemical comes into contact with the pest during the period of its potency; this point is most important because of the increasing use of the more short-lived organophosphorous and other pesticides.

Two publications of considerable importance are *Pesticide application methods* (Matthews, 1979), and the entire number of *Outlook on Agriculture*, vol. 10 (7) (1981) which is devoted to recent trends in spray application technology. In recent years spray application technology has become established as a scientific speciality in its own right, and much has been written, both in the two publications mentioned above, and also now in the latest editions of *Insecticide and fungicide handbook* (5th edition) by Martin & Worthing (1976), chapter 3, and the *Pest and disease control handbook*, by Scopes & Ledieu (1979), chapter 2.

Because of all the published information now available, in this book only the more important aspects are presented in summary and the other sources are cited for further details.

Most pesticides are either crystalline solids or oily liquids in the pure state or the technical product, and they are usually effective in quite small quantities (i.e. a litre or two per hectare). In order to apply a pesticide to a crop it is usually necessary for the chemical to be contained in a carrier fluid or powder. The earliest carrier (or diluent) used was water and the chemical was either dissolved in it or, if it was water-insoluble, as a suspension or emulsion. In the case of emulsions and suspensions it is important that the mixture be stable enough to ensure the application, under practical conditions, of a solution of uniform and known concentration. The physical stability of a spray solution may be conferred by the addition of supplementary materials. Thus the sedimentation of a suspension can be delayed by the addition of protective colloids or dispersing agents. The coalescence of the scattered droplets in an emulsion may be retarded by the addition of an emulsifier.

Formulations

As previously mentioned most pesticides are crystalline solids or oily liquids and as such are usually not suitable for spraying direct on to a crop. In a few cases the technical product is soluble in water; then the pesticides can be prepared as a very *concentrated solution* (c.s.) which only requires dilution by the farmer to the appropriate strength for spraying. Usually these concentrated solutions have to have wetting agents or detergents added (see later in the chapter). This type of spray solution is typically very homogeneous and spreads a very even level of pesticide over the foliage.

Many solid substances that will not dissolve in water can be ground and formulated as *wettable powders* (w.p.). Wettable powders are powders which can easily be wetted and do not resist the penetration of water, and are miscible in water in which they pass into suspension. Others are more accurately termed water-dispersible powders in that when mixed with water they remain as individual particles in suspension for a considerable period of time. Various additives (dispersants) can be included in the formulation of wettable powders to delay the process of sedimentation.

Oils and other water-immiscible liquids, if agitated with water, break up into tiny droplets which on standing rapidly coalesce to form a separate layer. This coalescence may be retarded or prevented by the addition of auxiliary materials known as surfactants or emulsifiers. With mixtures of oil and water, two types of *emulsion* are possible. The oil may be dispersed as fine droplets suspended in water, which is then the continuous phase, giving an oil-in-water (o/w) emulsion, or the water may be the disperse phase giving a water-in-oil (w/o) emulsion. The type of emulsion generally required for crop spraying practice is the o/w emulsion which, as water is the continuous phase, is readily dilutable with water. Thus pesticides insoluble in water may be dissolved in various organic solvents forming an *emulsifiable concentrate* (e.c.) which can be diluted in water to an appropriate spray strength. The 'breaking' of an emulsion is the usual way in which the toxic dispersed phase comes into play, breaking occurring after the evaporation of most of the water. Various chemical substances can cause the 'inversion' of an emulsion which then becomes useless for spray purposes. Sometimes emulsions are caused to 'cream' (named from the analogous creaming of milk), resulting

from differences in specific gravity between the dispersed and continuous phases.

Some pesticides are more suitably formulated as *miscible liquids* (m.l.). In this case the technical product is usually a liquid and is mixed (dissolved) with an organic solvent which is then, on dilution, dissolved in the water carrier.

Other pesticides may, for use against specific pests, be formulated as *seed dressings* (s.d.), both wet and dry, or *granules*, but these types will be dealt with later in the chapter.

At times it will be necessary to know precisely the quantity or proportion of the pure chemical in any formulation; sometimes this may be shown on the pesticide container, but more often is not. However, it will be available on the company data sheets, and in such sources as *The pesticide manual*. The usual method of expression of the proportion is as grams of *active ingredient* per kilogram of formulation (g a.i./kg) for powders, and grams per litre (g/1) for liquids.

Spraying

When water is the carrier, the usual method of application of the spray is by passage under pressure through special nozzles which distribute the chemical in a fine spray over the crop. In general, the type of spray application can, for convenience, be expressed as high-volume, low-volume, or ultra-low-volume according to the amount of carrier liquid.

During the last 40 years, especially when viewed worldwide, there have been many different definitions published for high- and low-volume spraying, with very little overall agreement as to rates. There has tended to be variation, not only from country to country, but sometimes according to the crop concerned, and also it appears according to the availability of local water supplies in some cases.

In the UK recently there has been a concerted effort to promote the following definitions.

		Rate (1/ha) for trees and bushes	Rate (1/ha) for ground crops
High-volume	(h.v.)	> 1000	> 700 (600)
Medium-volume	(m.v.)	500 – 1000	200 – 700
Low-volume	(l.v.)	200 – 500	50 – 200
Very-low-volume	(v.l.v.)	50 – 200	5 – 50
Ultra-low-volume	(u.l.v.)	< 50	< 5

High-volume spraying. As already mentioned, there have been many different definitions published over recent years, with little international agreement as to the rates. Even now in the UK there is not total agreement in that Matthews (1979) prefers the rate of 600 l/ha (more than) for field crops, as opposed to the more widely used 700 l/ha. An early definition of some authority was that by Maas (1971) who used the rate of 400 l/ha. However, at that time there was generally no 'medium-volume' rate. A distinction is now drawn between rates for tree crops and rates for field crops because of the need for good foliar spray cover, and the fact that the leaf area index for tree crops is usually far higher than ground crops.

With high-volume spraying the carrier is invariably water, and the usual quantity involved is in the region of 600–1200 l/ha. In the case of wanting a run-off of spray from the upper parts of the plants on to the lower parts, or on to the soil, then the water volume may be doubled up to the extent of 2400 l/ha. High-volume spraying has several major disadvantages, the first being the problem of transporting the large quantities of water required, especially in areas where piped water is not available. In many drier regions obtaining sufficient water for this purpose can be difficult. The cost of the high-volume spraying equipment is considerable, and the bulk of the equipment is such that its operation often requires a large tractor.

Medium-volume spraying. This is a somewhat arbitrary category, designated for convenience so that the other categories are more clearly defined, as with v.1.v.

Low-volume spraying. As now defined, this term applies to rates in the region of 50–500 l/ha, according to the type of crop being sprayed and the extent of its foliage cover. This technique was developed initially because of some of the problems associated with high-volume spraying.

Because of these problems alternative methods of application for the treatment of large areas have been sought. The 'scent spray' principle involves the jet of liquid being dispersed into fine droplets by the force of a copious air-flow. This method has been successful for the dispersal of DDT/petroleum mixtures from aeroplanes where the air speed alone is sufficient to break up the jet of solution into droplets which are then dispersed by the slipstream. A helicopter can be even more effective for this method using the down-draught from the rotor blades. For terrestrial use, the air-stream can be provided by a fan mounted horizontally, or by a turbine fan. These techniques, which rely upon the energy for spray dispersion being provided through the air-stream, and not, as in conventional spraying, through the liquid, are referred to as 'atomization'. Typically the droplets produced are much smaller than those produced by the usual high-volume sprayers. Because of the smaller droplet size smaller volumes of spray per hectare are needed and the use of organic solvents such as kerosene, petroleum oil, or fuel oil, in place of water, becomes economically feasible. If water is used as carrier, the concentration of active ingredient can be increased, thus giving rise to the term 'low-volume' spraying.

Not all low-volume spraying is done by aircraft, as there is some ground equipment suitable, but most of the aerial spraying done is low volume. The typical rates for ground application are commonly 100–200 l/ha, whereas for aerial application they were 15–75 l/ha. As mentioned previously, the equipment used for ground application is typically an air-blast machine, and the carrier liquids are frequently organic solvents, although water is used sometimes.

Ultra-low-volume (u.l.v.) spraying. This technique originally consisted of the production of very small droplets

(c. 70 μm) by a rotary atomizer, which were carried in a light oil and blown by a fan in drift spraying. Early u.l.v. work was mainly carried out aerially from light aircraft. When applying u.l.v. sprays the pilot flies higher than in conventional spray application (5–10 m instead of 1–2 m), often flying crosswind so as to use the movement of the ambient air to distribute the spray over the crop. The higher altitude increases the spray swath to about three times that of conventional aerial spray swaths (about 30 m as compared to 10 m). However, a recent trend is for aerial u.l.v. spray applications now being used to apply the spray from heights of 2–4 m using spray swaths of 15–25 m, depending on type of aircraft and equipment used; these conditions seem to be about optimum for aircraft u.l.v. applications. Because of the small amount of liquid to be sprayed, the total time required for the operation is usually much less than half that for conventional low-volume aircraft spraying.

U.l.v. ground-spraying was introduced relatively recently, and now very diversified equipment is being used. The advantages of changing from conventional methods to u.l.v. for ground spraying are less apparent than with aerial spraying, but there are some advantages, namely in *ultra-low dosage* spraying and in cases where transport of water is a problem.

The use of u.l.v. sprays requires fine droplets to ensure adequate cover but not so fine that losses due to drift and evaporation become too great. Recent development of rotary atomizers has ensured the production of a narrow spectrum of droplet size. Several manufacturers have been modifying their ground-spraying equipment for u.l.v. application.

The real establishment of u.l.v. techniques for crop spraying was in 1963 with the good results obtained with malathion for the control of cotton insects. From that time a great many papers have been published on this topic, and a large number of pests have been successfully controlled on a wide range of crops. Further information on u.l.v. techniques can be found in Maas (1971) and Matthews (1979).

Efficiency of insecticidal spray applications

The efficiency of a sprayer (applicator) is its ability to apply a known volume of liquid, at a known and steady rate of delivery, to a designated target area, with a regular and even spread of droplets. The efficiency of a spray application, in effect, is a combination of the mechanical efficiency of the equipment and that of the operator, and is measured ultimately by the proportion of pesticide actually reaching the target insect pest (and of course applies equally to any other form of pesticide application). With many field applications of pesticides the overall efficiency is frequently very low, often less than 1% of the insecticide actually reaching the insects, and sometimes much less.

In Fig. 29 is shown a diagram from Bottrell (1979) representing the fate of an aerial discharge of insecticide, regarded as reasonably typical.

Droplet size. The main objective in crop spraying is to spread the active chemical evenly over all the plant surfaces so that a lethal dose is available for the pest to pick up. When large spray volumes are used the final coverage is often far from complete due to the coalescence of drops and run-off. Thus the pesticide should be distributed over the plant surface in spray droplets that are as small as possible to produce a complete coverage. The droplet density required in a given spray operation depends upon various factors: type of pesticide (fungicide or insecticide); mobility of pest to be controlled; mode of action of insecticide (systemic, contact, or stomach poison). Thus when a contact insecticide is sprayed against a sluggish pest, a much higher droplet density is required than for the spraying of a stomach poison for the control of a highly mobile pest. In the case of fungicides an even better coverage is required for effective control.

Generally, the smallest droplet size would be the most effective, but very small droplets do not fall freely often being carried by wind and air currents. It appears that droplets of less than 30 µm are practically airborne they will be carried by the surrounding air so that they will not touch large target surfaces such as cotton leaves, but they may settle on small diameter targets such as the needles of coniferous plants, hairs of caterpillars, etc. Thus, for adult mosquito control, the optimum droplet size is 5–25 μm; for tsetse in vegetation, 10–30 μm. For agricultural crop spraying the situation is complicated; for many cotton pests it was found that droplet size of 20–50 μm was best, but typically many crop areas are relatively small and situated near other crops, which means that the spray must be deposited in a much more limited target area. Consequently the optimum droplet size in many crop-spraying operations will be decided upon mainly by the necessity to avoid spray drift, and thus larger droplet sizes will be used.

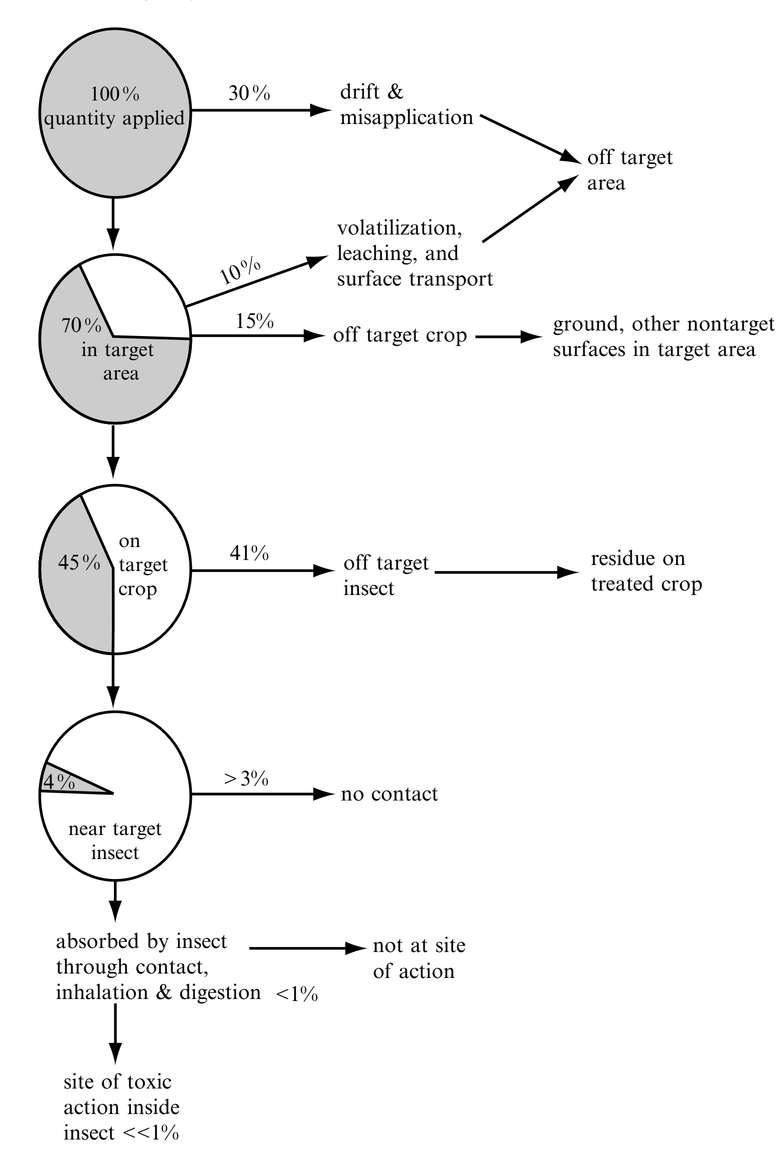
In aerial crop spraying for insect control, the optimum droplet size seems to be in the range of 80–120 μm, the lower values being more suitable for the treatment of larger areas only. In ground crop spraying the u.l.v. droplet size will be in the range 60–90 μm, although with systemic insecticides the optimum droplet size may be larger.

This is one aspect of spray technology that has received extensive study in recent years, and table 2.5 in Matthews (1979) lists the optimum size ranges for a selection of targets.

Target	*Droplet size*(μm)
Flying insects	10 – 50
Insects on foliage	30 – 50
Plant foliage	40 – 100
Soil (and drift avoidance)	250 – 500

Controlled droplet application (CDA). This term was coined in 1975, in discussions on herbicide application, in order to emphasize the importance of having a known and uniform size of droplet in sprays of liquid pesticides, but the basic

Fig. 29. The fate of an insecticide discharged by aircraft (Flint & van den Bosch, 1977, after von Rümker *et al*., 1974, from Bottrell, 1979).



concept had of course been known for a long time. However, awareness of the precise importance of droplet size in pesticide sprays, and methods of achieving both uniform droplet size and pattern is relatively recent (Matthews, 1977, 1979).

Solvents. Anyone with an elementary knowledge of applied mathematics will be aware that the volume of a sphere increase according to the cube of its linear measurement (radius or diameter) whereas the surface area increases according to the square. Thus smaller droplets have relatively large surface areas, which implies that the rate of evaporation of spray droplets is higher with smaller droplets. Consequently, solvents used in u.l.v. formulations must have low evaporation rates, and water should never be used. The more volatile liquids would also lead to evaporation of the solvent in the atomizer and might cause crystallization of the pesticide there. Liquid pesticides are sometimes sprayed undiluted in u.l.v. application, but more often some solvent is required.

The solvent must be non-phytotoxic, of low volatility, of high dissolving power for the pesticide, of low viscosity, and compatible with the pesticide. Not many of the solvents generally available will fit all these categories and so clearly good u.l.v. solvents are difficult to find. Xylene is too volatile, other aromatic hydrocarbons of lower volatility are often highly phytotoxic. Alcohols and ketones show higher

phytotoxic effects at lower volatility, and other common solvents show the same variations in properties. Sometimes a mixture of various solvents can be used with reasonable success. In the laboratories of Phillips–Duphar have been developed several compounds called *adjuvants* which dramatically decrease the phytotoxicity of many low-volatile solvents, thus the range of solvents that can be used for u.l.v. formulations has now increased. Conventional emulsifiable concentrates usually have a low flash point, but this seldom represents a fire hazard since the concentrate is mixed with a large volume of water before spraying. However, with u.l.v. techniques the solvent must be of low volatility for with rotary atomizers with electrical systems and many rotating parts the possibility of electrical discharge is always present.

With the use of these adjuvants a wider range of low-volatile solvents can be used for u.l.v. formulations and many of these formulations are now regarded as being special ultra-low-volume (s.u.l.v.) formulations. Their characteristics are high concentration, low volatility, low phytotoxicity, with a much lower viscosity than most u.l.v. preparations, and with a flash point above 75°C.

Spray residues. In conventional spraying the spray liquid contains a large amount of water, containing various wetting agents, dispersants and emulsifiers. The pesticide is generally present as a finely dispersed phase, solid in the case of wettable powders, or liquid when using emulsions. In u.l.v. sprays the pesticide is generally present as a true solution in an oil carrier, or sometimes the technical material is sprayed as such. Such differences in the spray make-up will have a profound effect on the behaviour of the spray droplets on the biological target.

After deposition of a spray droplet on a leaf, the droplet will assume a certain shape by spreading over the leaf surface. With conventional aqueous spray liquids this spreading depends greatly on the properties of the leaf: on hydrophilic leaves the droplet will spread to a thin film, but on hydrophobic leaves the droplets usually retain their spherical shape. The spreading of oils on most smooth leaf surfaces is much better than that of aqueous solutions. The s.u.l.v. formulations spread to a thin film on most leaves, even hydrophobic leaves, with very little run-off. However, there are times when run-off is wanted, and in these cases u.l.v. application is not the most suitable method of application.

The formation of a residue from an emulsion droplet is very complicated; evaporation of the water, breaking of the emulsion, and crystallization of the pesticide from the oil phase can occur simultaneously. Often from u.l.v. sprays the crystalline residue on the leaves is particularly coherent and very resistant to dislocation, and also the rain-fastness of u.l.v. residues seems to be better than that of conventional formulations.

Electrostatic spraying. A fairly recent innovation in crop spraying was developed by Coffee (1973), and termed electrostatic spraying. The basic principles are that the spray or dust particles are electrostatically charged and emitted from the nozzle region in a directed stream along the electrical field flux lines so that they surround the earthed target (crop plant), and the result is usually a very even cover of particles on both sides of the leaves. Since the particles are similarly charged they settle evenly on the leaves due to mutual repulsion and as there is a positive reaction on the tiny particles to the target leaves spray drift is minimized.

The method was initially developed using insecticide dusts but has since been adapted for use with low-volume sprays, and it would seem that this method of insecticide application has great potential commercially, particularly for small farmers.

The development studies on this method of pesticide application are mostly being conducted in Africa and especially on cotton crops. Since this crop is generally grown in dry areas the smallholder farmers constantly face a problem in providing water for more conventional spraying systems.

Dusting

Sometimes it is more convenient to use a dust instead of a spray: the need for water is obviated; the dust may be bought ready for use and is more easy to handle than spray concentrate; the dusting appliances are generally lighter and easier to manipulate than sprayers. For dusting, the active ingredient is diluted with a suitable finely divided ‘carrier’ powder, such as talc. The dust is usually applied by introduction into the airstream of a fan or turbine blower. However, in practice, dusts are often not easy to apply; frequently the powder ‘cakes’, usually through absorption of atmospheric moisture, or ‘balls’ in the hopper (through static electrification). Also it is difficult to ensure that the dust is homogeneously mixed.

It is generally found that dusting is only practicable in the calmest weather, and that best results are obtained when the dust is applied to wet or dew-covered plants. When dusts are applied to dry foliage usually not more than 10–15% of the applied material sticks to the foliage. Thus there are not many occasions when dusting is a more suitable application method than spraying.

Fumigation

The toxicity of a gas to a pest is proportional to its concentration and to the time of exposure against that pest. Research into gas properties has shown that usually fumigation is only successful in completely closed spaces or with special precautions to lengthen the time of exposure. For stored-products fumigation, the material can either be treated in special chambers or under large gas-proof sheets. Some field crops are treated by drag sheet techniques in which the fumigant is enclosed below a light impervious sheet dragged at a rate dependent on its length behind the vaporizing appliance.

Soil can be fumigated by the injection of volatile liquids directly into the soil at frequent regular intervals. The ‘DD’ soil injector is used to control nematodes and other soil pests, but it is a tedious process only suitable for relatively small areas.

Smoke generators contain a blend of the pesticides and a combustible mixture which burns in a self-sustained reaction at a low temperature, so that the minimum amount of pesticide is destroyed during volatilization, and the finely dispersed pesticide is carried in the cloud of smoke.

Aerosols contain the toxicant dissolved in an inert liquid which is gaseous at ordinary temperatures but liquefiable under pressure. When the pressure is released, the solution is discharged through a fine nozzle, the solvent evaporates and the toxicant is dispersed in a very finely-divided state. Methyl chloride, at 5.5 bar, and dichlorodifluoromethane ('Freon') at 6.2 bar at ordinary temperatures are two widely used aerosol solvents.

The earlier aerosols were used against medical and household pests, and were not suitable for use on plants as the carrier was usually strongly phytotoxic; but now there are water-based aerosols (usually employing a mixture of synergized pyrethroids) available for garden use on cultivated plants.

Seed dressings

The earliest form of seed dressing was to steep the seed in liquids such as urine or wine. The object of a seed dressing is to protect the seed in the soil and also to protect the seedling for a period after germination. The dressing will form a protective zone around the seed, and the extent of the zone will depend upon whether the pesticide has any fumigant or systemic action. In the past, seed dressings have been used mainly against smuts and other diseases, but now there are many insecticides which can be successfully formulated as seed dressings against insect pests such as wireworms, chafer larvae and shoot flies, and preparations of systemic compounds will protect against aphids and other sap-sucking insects on the young plants. Seed dressings can be liquids which are adsorbed on to the seed coat, or powders which are either sufficiently adhesive to stick directly on to the seed coat or else have to be stuck to the seed with the aid of a 'sticker' (paraffin or methyl cellulose).

With the advent of precision seed drilling came the development of *pelleted seed*. The object of seed pelleting is to make an irregular-shaped, rough seed (e.g. sugar beet) into a smooth spherical shape so that it will pass easily through the drill. Also a very small seed (e.g. *Brassica* seed) is given more bulk for easier handling. A few major seed companies are now supplying an ever-increasing range of pelleted seeds. The pellet is composed of inert material (such as powdered clay, pumice or Fuller's earth), and clearly during the pelleting process it is easy to incorporate pesticides into the pellet. The process is quite expensive though, and at times of soil water shortage pelleted seed suffers from impaired germination.

Granules

A new method of pesticide formulation was that of granules; these are small solid particles and are now widely used for the treatment of seedling crops with systemic organophosphorous and carbamate insecticides. The main advantage of granular formulations is that the insecticide can be placed in such a manner that gives maximum protection to the plant, with minimal danger of large-scale soil pollution and negligible danger to the operator. This is of particular importance with highly toxic chemicals. Another major advantage of granules is that the active ingredient is less affected by the soil than would otherwise be the case. Many pesticides are strongly adsorbed in soil and rapidly become ineffective once they reach it. The rate at which the pesticide escapes from granular formulations is mainly controlled by the rate of leaching by rain water. However, the organophosphorous compounds used in granules are generally of low aqueous solubility. Other major factors controlling rate of pesticide release from granules are temperature, dosage, and size of granule. The six major organophosphorous insecticides initially formulated as granules were aldicarb, dimethoate, phorate, disulfoton, chlorfenvinphos and diazinon, used against fly maggots, beetle larvae, aphids and nematodes. Now many new and very toxic organophosphates are formulated as granules for safety reasons. Granules are sometimes applied broadcast, but more typically as row treatments at sowing by bow-wave technique or where labour permits by spot applications round the base of individual plants using hand applicators – 'Rogor' and 'Birlane' applicators are generally available for this purpose. The body of the granule is made of various inert substances; for soil application both phorate and disulfoton granules are made of Fuller's earth. Also used are coal, rice husks, corn cob grits, gypsum and other minerals. On occasions it is advantageous to make a foliar application of granules and there is a pumice formulation for this purpose; pumice is more expensive as a base but is lighter, stickier, and more effective for foliar lodging.

Encapsulation

The most recent development in pesticide formulation is the technique of micro-encapsulation. Work at Rothamsted Research Station, England, has shown that it is possible to encapsulate an insecticide in a non-volatile envelope of cross-linked gelatine in such a way that it is non-toxic by contact, but is toxic to insects ingesting it. By the addition of suitable stickers the formulation can be given considerable resistance to weathering. This type of formation would appear to be of great promise for the control of leaf-eating insects. The formulation has the advantage of being far safer to handle than other pesticide formulations where very toxic chemicals are being used, and it presents far fewer hazards to beneficial insects such as predators, parasites and pollinators. The capsules are so tiny that the formulation has the appearance of being a slightly coarse powder. However there have been reports that honey bees collected the capsules mistakenly for pollen grains, which are about the same size, and that this caused a number of larval deaths in the hives.

Where a contact kill is required, it is possible to prepare leaking capsules which will release the poison over a period of time. At Rothamsted it was found that under warm conditions a standard wettable powder of DDT lost over 90% from the target area in 35 days, while a leaking capsule formulation lost about 20% over the same period.

Baits

The use of poison baits in pest control is generally confined to the insect groups Orthoptera (crickets, cockroaches, sometimes locusts), Isoptera (termites) and Hymenoptera (ants), in addition to terrestrial molluscs and vertebrates (especially birds and rodents). These pests are typically gregarious with underground nests. Social insects in nests are particularly difficult to kill by spraying insecticides, and sometimes the nests are hard to locate. Most social insects take food back to the nest where it is shared by trophallaxis amongst other adults and the larvae. In the case of fungus-growing termites (family Termitidae) and ants (tribe Attini), the collected food material is incorporated into the fungus gardens on which the fungus grows and poisons introduced in this manner eventually get distributed throughout the colony.

The earliest poison baits relied upon inorganic stomach poisons such as salts of arsenic, lead, mercury and sodium fluoride, but these have now largely been replaced by certain organochlorine compounds.

Poison baits generally comprise four separate components (Cherrett & Lewis, 1974).

(1) *Carrier or matrix*: inert material which provides the structure of the bait. This may be an edible or attractive material such as meal (e.g. soyabean, groundnut) or citrus pulp, or a more inert or less attractive substance such as ground rice husks, corn cob grits, clay, vermiculite and gelatine microcapsules.

(2) *Attractants*: this may be an integral part of the carrier itself (e.g. soyabean meal, citrus pulp), or may be substances such as sugar, molasses, or vegetable oils added to the inert carrier base. A recent development in leaf-cutting ant baits is the incorporation of a trail pheromone to attract the worker ants to the baits. Obviously any chemical that will induce the insects to pick up, or eat, the bait will make this method of control more successful.

(3) *To*xicant (poison): previously usually a stomach poison, but more recently contact insecticides such as aldrin, dieldrin, and heptachlor are being used.

(4) *Additives*: for specific formulation purposes, such as preservatives, materials to bind the bait together in pellets or blocks, and waterproofing agents. The physical properties of baits can be important, especially for use in the tropics with high temperatures, high humidity and torrential monsoon rains. For a broadcast bait to remain effective in the field for several weeks under wet tropical conditions it must not disintegrate in the rain. A standard ant bait is 'Mirex 450', but the compressed pellets apparently break down in heavy rain and become ineffective. Experiments by Cherrett and others have shown that leaf-cutting ant baits composed of citrus pulp with soyabean oil and aldrin can be rendered fairly waterproof by the addition of a hydrophobic surface deposit of siloxane, which prolongs the effective life of the bait under wet conditions.

Baits are often placed by hand, but clearly this is time-consuming and costly at present times, in most countries, and recent trials against leaf-cutting ants in C. America have used aerial application from low altitude with considerable success.

Another type of baiting is the use of spot sprays against adult fruit flies (Tephritidae). This technique involves the spraying of spots (i.e. squirts or blobs) of mixture, about 10 ml in volume each, scattered throughout the foliage in the orchard or plantation. The viscous liquid applied in this manner consists of protein 'solids' (hydrolysates) with added malathion as the toxicant; for full details see Drew, Hopper & Bateman (1978).

Systemic pesticides

Certain pesticides are capable of entering the plant body and being translocated to other parts of the plant through either the phloem or xylem systems. These insecticides may be applied as sprays on to the soil, sprays on to the foliage, granules on to the soil, or a foliar application of granules, or in the case of woody plants direct injection into the phloem system can be made using special injectors. Sap-feeding insects, such as aphids, are more readily killed by systemic insecticides than by those with a contact action. Parasites and predators are not affected unless they come into contact with the insecticide, that is if the plants are sprayed. Some of these insecticides are highly poisonous to man, but others are now available (such as malathion, trichlorphon and menazon) which are still effective against the insect pests but with reduced toxicity to man.

A systemic insecticide must persist in the plant body in an active form until the contaminated sap is sucked or eaten by the insect pests. There are, however, no problems of surface adhesion and weathering, although the problem of penetrating the plant has to be overcome. Consequently, these insecticides are sufficiently lipid-soluble to enable them to penetrate the plant cuticle and also soluble enough in water to be easily translocated within the plant.

They must also resist hydrolysis and enzymatic degradation for a sufficiently lengthy period of time to be effective as a pesticide. Obviously, not many insecticides possess this subtle balance between lipophilic and hydrophilic properties and, of course, non-phytotoxic at insecticidal concentrations.

The term systemic is not always used in the same sense: sometimes the substances taken up by the plant roots are not referred to under this heading.

Some pesticides which can penetrate the plant cuticle and pass through the cells are termed *translaminar* (or *penetrant*) pesticides. These can penetrate the leaf cuticle and will pass through the leaf to the other surface: hence pests on the underneath of the leaf can be killed by spraying the pesticide on the upper surface, and it can also kill leaf-miners effectively. These pesticides are not usually transmitted through either phloem or xylem systems but just diffuse through the cells. Examples include fenthion, fenitrothion, trichlorfon, pirimphos-methyl.

Pesticide deposition and persistence

In temperate countries a considerable amount is known about the proportion of pesticide reaching the target area, and how long it persists there. The relationship between the amount of pesticide present and the control of the pest obtained is thus fairly well established.

The object of a pesticide spray programme is firstly to 'hit' the target, that is to place sufficient quantity of the chemical either directly on to the pest organism itself or on to the place the pest inhabits so that the pest will come into contact with enough of the poison to kill it. The second object is that enough of the pesticide remains on the foliage for sufficient duration to kill the required proportion of the pest population.

Hitting the target is often quite difficult for many pests live on the underneath surface of leaves where they are quite sheltered. Or they may live in the denser foliage in the centre of bushes, or the plants may be so closely planted that it is difficult to spray between them, or the tree too tall for the uppermost leaves to be reached. This point has already been mentioned on page 36. Then the question of persistence remains. Most spraying is done on to plant foliage and so the general target area is leaf surface. The main aspects to be considered are enumerated below.

(1) Collection of the pesticide droplets on the leaf surface (i.e. 'hitting' the target area).
   (a) Droplet size and density: coalescence.
   (b) Spray velocity: impaction of droplets determines collection success.
   (c) Angle of contact between spray and leaf surface.
   (d) Leaf surface texture (i.e. wettability); waxy or hairy leaves tend to deflect spray droplets.
   (e) Quantity of carrier and run-off: includes droplet coalescence with subsequent run-off; deliberate run-off is sometimes the aim, either to redistribute the chemical to lower leaves or on to the soil (as for cutworm control).

(2) Weathering of the spray residue on the leaves (i.e. chemical retention).
   (a) Rain run-off: redistribution to lower leaves can be advantageous, otherwise wash-off on to the soil usually means wasted pesticide.
   (b) Degradation of the chemical (sometimes the breakdown products are still insecticidal, so effectiveness may not be reduced).
      (i) Volatilization (i.e. vaporization): this can be an advantage in an enclosed space (i.e. stored products container).
      (ii) Temperature (thermal) breakdown.
      (iii) Solar radiation; either photodegradation or reaction with other radiations of a solar origin.
      (iv) Breakdown by soil micro-organisms.

A great deal of experimental work has been done in laboratories and in small plot field experiments on these problems of deposition and persistence, as reported by Matthews (1979). But in practical terms the situation is usually very complicated, and most field applications of pesticides are made with a low level of precision, which accounts in part for the tremendous variation in results that are typical. In general, in most crop/pest situations there are so many variable factors that it is extremely difficult to take appropriate account of all of them, which is why most control programmes are rather inefficient.

Pesticide degradation by micro-organisms. A recent discovery (first noticed in the late 1970s) in the USA has led to awareness that in some soils micro-organisms are causing rapid degradation of some pesticides so that they have little effect. The precise mechanisms involved are not yet understood. The chemicals involved in this accelerated degradation are mostly herbicides (thiocarbamates whose active ingredient is eptam), but also the carbofuran insecticides sold as 'Furadan'.

Whether this phenomenon will become widespread is not at all clear, but the implications are serious especially when considering the increase in the practice of no-till and low-till farming with its concomitant use of soil pesticides.

Temperature. At Rothamsted, experiments have shown that temperatures would be reached on isolated surfaces in the tropics such that no non-systemic insecticide applied in commonly used formulations would persist for more than a few days. Under tropical conditions the majority of even the most persistent insecticides may be lost from the target surface in a few days. For example, dieldrin deposits lost 25% at 20°C and 95% at 40°C, in 24 hours, at the same low wind speeds (2 mph). However, when the deposit level is very low (about 0.005 $\mu g/cm^2$ on a glass surface; 0.01–0.02 $\mu g/cm^2$ on a cotton leaf) it no longer obeys these rules, but remains very firmly bound to the surface for a very long period. These data are likely to apply to insecticides applied as sprays of wettable powders, emulsions, or dusts.

Work done at Beltsville, MD, USA, in 1975 on solar degradation of pesticides in hot weather showed that, after application of dieldrin and heptachlor as sprays on short grassland (5 kg/ha) during hot sunny weather, volatilization was so great that the half-life of dieldrin was 2.7 days and for

the heptachlor 1.7 days, and after 30 days there was 10% of the dieldrin left and 4% of the heptachlor.

Most agricultural crops are completely exposed to the sun and so the above result can be expected, although for some plantation crops the trees may form a canopy with shade underneath. Dieldrin applied to tree trunks and the underneath of branches for Tsetse Fly control will persist, since it is shaded from direct sunlight, and effectively kill Tsetse resting there for periods of up to four to five months.

Unfortunately, however, not a great deal of research into the persistence of most insecticides has actually been carried out in tropical countries and often spray programmes tend to be too speculative.

In temperate regions the cold winter conditions inhibit pesticide degradation and there is usually little breakdown over the winter period; this is one of the reasons why there was such dramatic chemical build-up in the soil in parts of the UK, Europe and N. America in the days when DDT and dieldrin were widely used.

Rain. Most parts of the wet tropics receive their annual rainfall torrentially and it is expected that insecticide residues on crop plant foliage will be washed off at a far greater rate than similar residues exposed to the more gentle temperate rainfall.

Tropical rain is often a problem, but in temperate regions rainfall is seldom serious. The only time it presents a problem is if rain falls immediately after a spray application to crop foliage, then the spray will be washed to the soil. The operator is expected to exercise some judgement in deciding when to apply a crop spray; unexpected showers of course sometimes necessitate an immediate additional spray. Once the spray residue is dried on the plant foliage most temperate rains do not wash off very much.

Spray additives

Spreaders (sometimes called *wetters* or *surfactants*) are substances added to the spray to reduce the surface tension of the droplets so as to facilitate contact between spray and sprayed surface. Plain water falling on a waxy leaf such as that of a *Brassica* will normally collect in large drops and will then run off, leaving the leaf surface dry. The incorporation of a spreader is now standard production practice in the manufacture of most modern pesticides. For crops with particularly waxy leaves (such as brassicas) or against pests with particularly waxy cuticles (like mealybugs, and Woolly Apple Aphid) it is necessary to add extra spreader to the spray solution. Sometimes when extensive run-off is required to enable the pesticide to penetrate to the lower part of a dense crop, this can be achieved by addition of extra spreader to the spray. From a physical point of view wetting and spreading are not quite the same, but for practical purposes they can be regarded as synonymous. Spreaders and surfactants exist in three forms: non-ionic, anionic and cationic, classified according to their ionizing properties. Surfactants are defined as surface-active components. The non-ionic detergents depend upon a balance between hydrophilic and lipophilic properties throughout the molecule for their wetting properties. The advantages of these substances include the fact that they are incapable of reacting with cations or anions present in other spray components and in hard water, and that they are not hydrolysed in either acidic or alkaline solutions. However, phytotoxicity of supplements has to be taken into account. Anionic spreaders possess a negative charge on the amphipathic ion, and typical examples include soap, sulphated alcohols and sulphonated hydrocarbons. Cationic spreaders carry a positive charge on the amphipathic ion and a negative charge on the gegenion, and examples include the quarternary ammonium and pyridinium salts. The advantage of cationic spreaders is that they cannot react with ions of heavy metals. The incompatibility of anionic and cationic additives must be borne in mind if it is necessary to add several supplements to a spray mixture.

Dispersants. Sprays must be of uniform concentration and with suspensions there is always the danger of sedimentation. By the addition of a dispersant (or protective colloid) sedimentation can be effectively delayed. The more effective colloids used as dispersants are the methyl celluloses and the sodium carboxymethyl celluloses.

Emulsifiers. These are added to emulsions to modify the properties of the interface between the disperse and continuous phases. Many of the spreaders or surfactants also function as emulsifiers (e.g. soap).

Penetrants. Oils may be added to a spray to enable it to penetrate the waxy cuticle of an insect more effectively. Some of the more effective sprays against locusts were solutions of dieldrin in light petroleum oils.

Humectants. These are substances added to a spray to delay evaporation of the water carrier, and the more commonly used compounds are glycerol and various glycols. They are more frequently used with herbicides than insecticides.

Stickers. Stickers such as methyl cellulose, gelatine, various oils and gums, are used to improve the tenacity of a spray residue on the leaves of the crop. Maximum spray retention is particularly important in the tropics where rainfall is often monsoonal and torrential. Generally a fine particle deposit is more tenacious than one of coarse particles. Spreaders usually enhance the tenacity of a deposit and its retention on the plant, although they may retain their wetting properties and thus cause the deposit to be washed off by rain or dew. Some spreaders break down on drying and form insoluble derivatives and these can greatly enhance retention of the deposit.

Lacquers. In order to achieve a slow release of a pesticide in certain locations it is possible to formulate some insecticides into lacquer, varnish or paint. The painted area then releases the insecticide slowly over a lengthy period of time.

The insecticides used in this manner were mainly organochlorines and particularly DDT and dieldrin. Incorporation of insecticides into paint is of some value but the lacquers are of limited use owing to the problem of the lacquer remaining after the pesticide has dispersed. This practice is of more use against household and stored products pests than crop pests.

Waterproofing. Baits used in the tropics where they are exposed to torrential rainfall are liable to disintegrate in the rain, and hence lose their effectiveness. As mentioned on page 127, Cherrett and others have shown that leaf-cutting ant baits can be rendered sufficiently waterproof by the addition of a hydrophobic surface deposit of siloxane, without reducing the attractiveness of the bait to the foraging ants.

Synergists. These are substances which cause a particular pesticide to have an enhanced killing power. They are sometimes called *activators*. The way in which synergists act is not always fully understood, but some operate on a biochemical level inhibiting enzyme systems which would otherwise destroy the toxicant. Usually the synergist itself is not insecticidal. Piperonyl butoxide is a synergist for the pyrethrins and certain carbamates. Some pairs of organophosphorous insecticides have a mutually synergistic action (sometimes called '*potentiation*', especially in American literature). Other synergists include piprotal, propyl isome, sesamin and sesamex. Many of these are particularly effective on the pyrethrins.

Equipment for application

As already mentioned, pesticide application technology has now reached quite an advanced stage and in view of the excellent publication by Matthews (1979), and the many papers in *Pesticide Science*, *Agricultural Aviation*, *Tropical Pest Management* (formerly *PANS*), and the like, it would be presumptuous to attempt an adequate coverage of this topic in a few pages, so this section is limited to just a few of the more obvious aspects in very brief outline; for details see Matthews (1979) and also Rose (1963).

High- and low-volume spraying

As previously mentioned, the usual amount of carrier liquid (water) for high-volume spraying is quantities in excess of 600 l/ha, typically 600–1100 l/ha, and occasionally as much as 2200 l/ha.

Whilst low-volume spraying uses water volumes in the region of 50–500 l/ha, typically the rates are 15–75 l/ha for aerial application, and 100–200 l/ha for ground application. All spraying systems consist basically of a tank for holding the spray liquid, a device for applying pressure to the liquid, and a nozzle or outlet through which the liquid is forced. Thus the only basic difference between equipment for low-volume spraying and that for high-volume is the capacity of the tank. The different types of high- and low-volume sprayers are very numerous but certain types can be categorized as follows.

Hand sprayers

Compression systems

Atomizers. These consist of a simple compression cylinder with an inlet at one end for the air and an outlet at the other for the compressed air. A plunger is moved up and down the cylinder to produce the compressed air. There are seldom valves present. The outlet tube is fixed at right-angles to a fine tube leading from the liquid container, and on the compression stroke the air is forced across the open end of the feed tube and creates a vacuum which draws up the spray liquid from the tank. As the liquid is drawn up it is broken up into tiny droplets by the air-stream. Hand atomizers are useful for treating individual plants, but they are tiring to operate for long periods. On the more refined atomizers the spray is delivered continuously by means of a pressure build-up system.

Pneumatic hand sprayers. These are machines with a tank capacity varying from a half to three litres and the tank acts as a pressure chamber. An air pump is attached to the chamber and it projects inside. The outlet pipe runs from the bottom of the tank and ends in a nozzle externally. Air is pumped into the tank which compresses the liquid and forces it out of the nozzle when the release valve is opened. On release, the spray is forced out by the air pressure in a continuous fine spray. The better machines can deliver a continuous spray for up to about five minutes when fully charged with compressed air. These sprayers are most useful in glasshouses or for treatment of individual bushes under calm conditions. As with the previous type these sprayers use very fine nozzles and as such are more suitable for use with solutions or emulsions than suspensions, which tend to block the aperture.

Knapsack pneumatic sprayers. These are basically the same as pneumatic hand sprayers except that they are designed for spraying large quantities of liquid (tank capacity up to 23 l). The tank is usually carried on the operator's back, suspended on a harness with shoulder straps. The outlet pipe is extended by means of flexible tubing and terminates in some form of hand lance. The lance usually carries from one to four nozzles, and is easily carried in one hand. A hand valve on the lance base controls the flow of liquid. The air pump is operated with the sprayer on the ground, and a high pressure is normally built up, which will last for about ten minutes of operation. These sprayers are manufactured in a wide variety of models, of varying degrees of efficiency. In general they are very useful, especially for the small farmer or for pesticide trial work. They can be very effective for estate work when teams of operators are employed, and individual attention for the plant is required. Since no system of agitation is incorporated, knapsack sprayers are more suitable for use with solutions than with suspended materials. Very long lances can be obtained for orchard and plantation use.

Pump systems

Syringes. Syringes consist of a cylinder into which the spray liquid is drawn on the return stroke of the plunger, and expelled on the compression stroke. The spray is sucked in through the spray nozzle aperture, or else through a separate ballvalve-controlled inlet near the nozzle. The spray produced is drenching, and the syringe is difficult and tedious to use; but they are useful for spraying small numbers of plants. Most syringes are simple in construction, and will last for years with minimum maintenance.

Force-pump sprayers. These are sprayers with a hand-operated pump, with a lance and nozzle outlet and a feed-pipe to draw the spray liquid from a separate container. Although small in size, these sprayers (fitted with a 45 cm double-action pump) can throw a jet of spray up to a height of 12 m. These sprayers are good for spot treatments in orchards, and, provided that the solution is kept stirred, they will spray suspensions as well as solutions and emulsions. This type of sprayer is obviously tiring to use and it is quite difficult to control the rate of application, but due to the double-action hand pump the spray is continuous.

Stirrup-pump sprayers. These consist of a double-action pump suspended in a bucket. For support there is a foot stirrup reaching to the ground on the outside. A flexible outlet pipe carries the spray liquid from the pump to the spray lance which may vary in length and arrangement of nozzles. A stirrup-pump sprayer requires two operators, one to hold the lance and direct the spray, the other to stir the solution (if it is a suspension) and to work the pump. They are very useful, all-purpose machines, of robust construction which will withstand hard wear. Bush crops, buildings, and small trees can be easily sprayed with a stirrup-pump sprayer, and it is ideal for team operation. Providing the liquid is kept stirred, then quite coarse suspensions can be sprayed. A large version, mounted on wheels, with a large capacity double-action pump is available for treating larger areas.

Knapsack sprayers. These are the all-purpose, very successful, sprayers used throughout the world for spraying pesticides over smaller areas. They consist basically of a spray container which sits comfortably on the back of the operator held by shoulder straps. The pump is of double-action, built either inside or outside the spray container, and is operated by working a lever which projects alongside the operator's body. In some models the pump lever also operates an agitation paddle in the spray tank. The spray liquid is applied through a lance held in the operator's free hand; the lance is connected to the spray tank by a long flexible hose. The tank capacity is usually about 231. Provided that a sufficiently coarse spray nozzle is used, this sprayer can be used with any type of spray. Many of the most recent knapsack sprayers are almost entirely made of plastic, which obviates the problem of metal corrosion by the more corrosive pesticides. With a little practice the rate of spray application can be controlled quite accurately. Knapsack sprayers can be tiring to operate over a long period of time, but they are very versatile, quite robust in construction, very portable, and most useful on small farms or in teams on larger estates, or for pesticide trials.

Power-operated sprayers

Compression systems

Hand guns. Two types of compression hand-spray guns are made. One type has the spray liquid fed into a pipe through which air from a portable compressor is fed. The other type is similar to the small compressed-air spray that is worked by hand, but the air pump is replaced by an inlet from a portable compressor. Droplet size, and rate of application, can usually be carefully controlled, but the capacity of the spray tank is small and hand guns are only of value where small areas have to be covered with small amounts of spray. Suspensions may block the outlet nozzle, especially if it is of very small aperture. The advantage of these sprayers is that any type of compressor can be used, and they may also be used as paint sprayers.

Portable sprayers. Many types of small portable sprayers are manufactured; some can be carried easily by one man and others are larger and mounted on a wheeled chassis. Air is compressed by a small compressor and is forced into the spray container. The container usually holds about 451, is of strong welded construction and is operated at a pressure of about 7 bar. The outlet hose from the spray container may end either in single or multiple lances, or may end in a boom. Provided the spray tank is lined with an anticorrosive material, these sprayers can be used for spraying corrosive liquids, since there is no pump to be corroded. As the compressor can be used for other purposes these machines can be useful to the smaller grower, who of necessity requires versatility in his equipment.

Large mounted sprayers. These are basically similar to the smaller portable sprayers, but they have spray tanks of a much larger capacity, hence they require larger compressors. The whole machine is usually pulled by a tractor, and the outlet terminates in a spray boom of varying design, or else in a series of hand lances for the spraying of individual trees. The spray booms may cover 6–9 m or more in a single swath. The better booms can usually be adjusted for height to suit the crop being sprayed. Rates of application can be adjusted by altering the size of the jet aperture in the nozzles. The booms may be positioned vertically for fruit crop spraying. Typically these machines are usually used for low-volume pesticide application, and they may be mounted on aircraft or helicopters for low-volume aerial application.

Pump systems

Portable sprayers. The range of small portable sprayers available is now very extensive. They are all based upon the fundamental units of a power source, a pump and a spray tank. The smallest units consist of a small simple, double-action

reciprocal pump harnessed to a small air-cooled engine upon a framework so that it can be conveniently carried. The largest units may include a tank complete with positive agitator, mounted upon a four-wheeled chassis. The pump outlet pipe may supply a number of hand lances, depending upon the capacity of the pump. The mounted machines may have a small boom mounted so that they can spray ground crops. These sprayers are only really suitable for small areas of orchard or plantation crops, for generally two lances is the effective limit.

Large sprayers. These have a range of tank capacity varying from about 180–1800 l and may operate at very high pressures (up to 55 bar) with a high rate of delivery. They are invariably mounted on tractors and often have booms which will deliver from 50–3500 l/ha. Some of the larger booms are built vertically so that the nozzles point upwards, to ensure that the under-leaf is sprayed as well as the top surfaces; these are used particularly for crops such as coffee and fruit trees. These sprayers may be mounted on aircraft for aerial use, usually for low-volume application.

Low-volume mist blowers. Low-volume mist blowers and fogging machines are of relatively recent development. Since the water used in high-volume spraying is purely an inert carrier, use is made in the low-volume equipment of air-streams to carry the very finely dispersed spray droplets, and so far less water need be employed. The air-blast systems consist mainly of a series of nozzles which produce a coarse spray through wide apertures which is then broken into fine droplets by a fast-moving air-stream. This basic system has many modifications, mainly in the method in which the liquid is introduced into the air-stream to be broken up. The air-stream is usually produced by a centrifugal fan of large capacity. Mist blowers vary enormously in tank size, from portable machines that can be carried by one man to large, self-mounted, tractor-drawn machines. They can be used to spray in two different methods, either as blast spraying or drift spraying. Blast spraying is usually carried out in orchards, or plantations of such crops as apples, mangoes, coffee or rubber. The air all around each tree is replaced by a mixture of air and spray droplets, and generally a good, even cover is achieved using as little as 100 l/ha. Run-off of insecticide is eliminated, and the small droplets dry out quickly so the chemical becomes firmly attached to the foliage. Drift spraying relies upon the movement of ambient air to carry the insecticide mist through the crop, and hence its use is dependent upon favourable weather conditions. The optimum droplet size is thought to be about 80–120 μm; very fine droplets either evaporate or are lost in the wind and never settle, and larger droplets settle too rapidly. Mist blowers are expensive to buy, but very efficient; up to 30 ha of orchard can be sprayed by two operators in a day. Drift on to other crops is the main danger when using this type of sprayer.

Ultra-low-volume spraying

U.l.v. application technique was developed in E. Africa in the control of Desert Locust, shortly after World War II, using solutions of DNOC and dieldrin in diesel oil. Development of u.l.v. for crop spraying started much later. The technique consists essentially of the production of very small droplets (c. 70 μm) carried in a light oil and blown by a fan in drift spraying from light aircraft.

In the early 1960s much of the development work on u.l.v. was done by the Plant Pest Control Division of USDA in co-operation with American Cyanamid. When applying u.l.v. sprays the pilot generally flew the plane much higher (3–6 m) than in conventional spray application where the altitude is usually about 1–2 m. The higher altitude increases the spray swath to about three times that of the conventional aerial spray. Generally, with the Cyanamid u.l.v. method the spray swath was about 30 m compared to 12 m. (See also page 95.)

Electrostatic sprayers. The ICI ‘Electrodyne’ sprayer is a small, hand-held apparatus with a disposable combined bottle and nozzle (‘Bozzle’) containing the already formulated insecticide. The efficiency of the application appears to be very high, with minimal drift, but at present only the hand-held sprayer is commercially available; ICI stated that they expected it to be widely available in 1982. They hoped that tractor-mounted ‘Electrodyne’ sprayers might be available by 1983/4. For further details see Coffee (1973) or your local ICI representative.

Dusters

All dusters consist basically of a hopper (a container for the dust), a system of agitation to disturb the dust and a feed mechanism to pass the dust into a current of air which is carried through an outlet as a turbulent cloud.

Hand dusters are usually primitive in structure and tedious to use, but can be effective for the small farmer. They are often a crude distributing arrangement built as part of the packaging; either two concentric cylinders free to move within each other, or a cardboard piston or diaphragm for pumping the air. As the air passes through the pack it picks up a small quantity of dust and ejects it through a nozzle.

Hand pump dusters are cheap and easy to operate but do not have very much control over the amount of dust delivered. More advanced pumps have a double-action plunger which maintains a constant and even stream of air.

Bellows-type dusters generate the air-stream by the contraction and expansion of a pair of bellows. The commonest types are worn on the back in knapsack fashion. The dust hopper (containing from 3.5–7 kg of dust) is carried on the back in a metal cradle; the bellows are situated either on the back or top of the hopper and drive a stream of air through a tube into a small mixing chamber by the hopper outlet. The dust is fed into the mixing chamber by a simple agitator, and then the air and dust travel along a

flexible pipe running along the side of the operator, and can be controlled easily with one hand. The outlet may vary in shape and design for different purposes. The bellows and agitator are operated by a simple up-and-down movement of a lever worked by the free hand.

Rotary hand dusters produce an air-stream by a fan driven off a hand crank through a reduction gear. They are often mounted either on the chest of the operator or on his back, using a metal frame and system of straps.

Power dusters are manufactured in a variety of forms. Traction dusters derive their motive power from the turning of the land wheels, either as a wheelbarrow type or a two-wheeled trailer type. Wheelbarrow-type dusters are suitable for use on small areas only, whereas the trailer type is usually pulled by a tractor and has a much greater capacity. Power dusters are equipped with independent engines to provide the power for their operation. The smallest types can be strapped to the chest of the operator, but the larger types become very expensive. The larger power boom dusters are effective for treatment of large areas. Some of these dusters work on the drift principle and use the movement of ambient air to distribute the powder over the crop. Aeroplane dusting is carried out in areas where the terrain and crops are suitable, and again the air-stream is used to spread the powder over the crop.

Filters and nozzles

Two components of sprayers of particular importance are filters and nozzles. All spraying machines are equipped with a series of filters to ensure that no coarse particles are permitted to pass into the feedpipe and block the nozzles. Filters are vitally important, particularly since the mixing of the spray and the filling of the tank often take place in the field; without the main tank filter the spray would frequently become contaminated with insect bodies, leaves, pieces of grass, and other detritus, which would clog the nozzles and ruin the spray programme. At various points in the pipe system additional filters may be placed and the nozzles themselves may also be fitted with gauze filters in various positions according to their design.

Nozzles are the detachable apertures which break up the pesticide liquid into spray. Many different types of nozzles are made, and each gives its own particular spray pattern. The nozzle disc controls the final shape of the spray pattern. In *cone nozzles* (which have a spray pattern in the form of a hollow or solid cone) the disc is perforated by a series of small holes. In *fan nozzles* the perforation is an elongate, horizontal slit. Discs are often made either of tungsten steel or more recently in ceramics of various sorts, these materials being less subject to abrasion and wear. Cheap nozzles made of inferior materials soon abrade and then as the apertures enlarge the rate of spray application increases. Fan nozzles are generally less subject to wear than cone nozzles, but cone nozzles give a better breakdown of the water into droplets. The size of the apertures on the disc control the rate of spray delivery, but below a certain diameter the size does not greatly affect the size of droplet produced. Some nozzles can be adjusted to obtain droplet sizes from a fine mist to a heavy drenching spray. Pesticides in suspension have to be used with particular care for nozzles with small apertures can be easily blocked by them. For many of the better makes of sprayers a range of nozzles is available so that the most suitable nozzle for a particular purpose can be used. This is of great importance in spraying field trials because at the same rate of operation (i.e. pumping and walking with a knapsack sprayer) use of the different nozzles will give spray delivery rates in either the high-volume or low-volume ranges, according to the nozzle used. Using a very fine nozzle (low-volume) to put on a high-volume spray is exhausting to the operator, and conversely with a coarse nozzle it is almost impossible to apply a low-volume spray successfully.

8 *Pesticides in current use*

As previously mentioned, there are various ecological hazards associated with the repeated use of pesticides on crops, as they are mostly potent chemical poisons, but so far as can be seen agriculture will continue to rely heavily on their use for the forseeable future in the continuing battle with insect pests. What is important is that these poisons be used judicially; essentially this means the minimum dosage, and the fewest applications, for the maximum effect. This entails a high level of understanding, both of the chemicals themselves and the basic principles of pest control.

Historically the development of chemical control of insect pests started with the extensive cultivation of cotton in Egypt and the Sudan when insect damage threatened the success of this valuable crop. To this day cotton is still subjected to serious pest depradation – 1400 species of pests are recorded worldwide, and the present annual expenditure on pesticides is around £1.5 billion. Many cotton crops are still sprayed at weekly intervals for 15 weeks.

Types of pesticides

Although in this chapter pesticides are viewed basically according to their chemical structure, it should be remembered that their mode of action may be equally important, and on this basis they could be grouped as follows.

(a) *Repellants*. These work by keeping the insects away from the host plants by the use of repellent odours. In olden days the laying of kerosene-soaked sacks between crop rows had this effect; it also works by masking the typical olfactory signals from the host plant. At present mostly used against mosquitoes and other medical pests, and less often with crop plants.

(b) *Antifeedants*. Insects will land on the crop plants but these chemicals on the foliage inhibit feeding behaviour. Products from the Neem tree are proving to be very effective in this respect (see page 67).

(c) *Fumigants*. These are mostly volatile substances (liquids, and some powders) that vaporize under ambient conditions; it includes gases of various types. The gases are mostly used in food stores and other enclosed spaces; the volatile liquids likewise, and also for soil fumigation against nematodes (eelworms) and other soil pests.

(d) *Smokes*. These are finely divided powders mixed with a combustible material. As with fumigants, only suitable for use in an enclosed space, such as stored products pests, but also important in greenhouses.

(e) *Stomach poisons*. Only effective if ingested and absorbed through the intestinal tract. Usually applied to the foliage of the plant to be eaten by the pests with biting and chewing mouthparts; also mixed with baits to encourage ingestion.

(f) *Contact poisons*. These are absorbed directly through the insect cuticle.
   (i) *Ephemeral* – short-lived, and usually applied to the foliage.
   (ii) *Residual* – persistent (remain active for a long period of time). May be applied to foliage, but more often to soil for long-term activity.

(g) *Systemic poisons*. Watered on to the soil, or applied to tree trunks, or sprayed on to the foliage; absorbed by the plant and translocated through the plant body in the vascular system. Effective especially against sap-sucking and tunnelling insects; usually applied as a spray but granules are also employed. Translaminar pesticides can be absorbed through the leaves.

Pesticide recommendations

The number of pesticides with which I have personal experience is rather limited, and so recommendations have to be made on the basis of published information, both from the latest edition of the *Pesticide Manual* (10th ed., 1994), other general publications such as *Approved Products – 1984* (MAFF, 1984), etc., and data sheets from the chemical companies concerned. In some sources the data available are vague and include such statements as 'generally effective against soil (sap-sucking/foliage-eating) insects …', or 'effective against lepidopterous pests …'. The practising agricultural entomologist is clearly usually concerned with a particular pest (or pest complex) on a specific crop, and such vague recommendation is of limited use. As mentioned below, the effectiveness of a particular pesticide is a somewhat variable property which really requires quite specific definition. Thus in a book of this nature, where many different countries (and continents) are concerned, it is not feasible to make very specific pesticide recommendations, so only general recommendations are made together with information as to the more appropriate methods of application. For *detailed* pesticide usage, the local Ministry of Agriculture (or equivalent) recommendations should be consulted; they are generally published annually, and may even include supplements during the year as new information becomes available.

Pesticide effectiveness

As already mentioned, the *efficiency* of a pesticide is expressed as the more or less constant proportion of the population killed by the poison (under optimum conditions) regardless of the actual number of pests involved. The percentage killed by the poison under laboratory conditions (i.e. Potter Tower) may be quite constant, assuming no resistance has developed. *Effectiveness* (*sensu stricta*) is more concerned with the number of pests surviving after treatment, or more practically the extent of crop damage occurring after treatment.

In the remainder of this book, when considering control recommendations it is usual to apply the term '*effective*' in a broad sense (*sensu lato*) which embraces both aspects mentioned above; but students should be aware of the distinction. For critical testing of insecticides see Busuine (1971).

In the halcyon days when DDT and dieldrin were used so effectively against so many pests there was little need to query the factors affecting efficiency, since usually both were giving consistent kills of 98–99% under a wide range of conditions. Nowadays the alternative pesticides are far more variable in their effectiveness (*s.l.*) and much less predictable in terms of results.

Perusal of the pesticide literature indicates that for example some 60 chemicals are regarded as 'effective' against Lepidoptera (caterpillars), and about 50 are regarded as 'aphicides'. Clearly not all these compounds are equally effective and many will not be chosen for use in pest management schemes. In any pest population the application of a chemical poison (under controlled conditions) will only kill a certain proportion; part of the population will be killed very easily (by small doses), and at the other extreme a small number of pests will survive even a massive dose. This is generally true for all large populations of organisms studied epidemiologically. For experimental (comparative) assessment it is usual to use the rate responsible for mortality of half the trial population (hence LD_{50}). But, of course, for practical control purposes usually a kill of 95% or more is the aim, depending in part on the type of crop/produce. Unfortunately for the entomologist, on some crops there is economic (or political) pressure to aim at a kill-level of 98–99%, which in these post-organochlorine days is seldom feasible. Out of the total range of reportedly 'effective' pesticides against caterpillars or aphids, if applied under optimum conditions at the optimum dose rate (see below), it may be expected that some chemicals can give a kill of 98%, whereas others will range from 90, 80, 70, 60, or even 50 or less percentage kill. Clearly the latter chemicals will not be used in most pest management programmes, unless, for example, they are *very* cheap.

This scale of pesticide effectiveness is to be expected in respect to use under optimum conditions and at optimum dosage. On consideration of the range of environmental conditions to be expected in the field, the variation in dose rates and application methods, etc., the end-result can be quite horrendous variation in relative effectiveness. It should also be pointed out that the range of results recorded for one species of aphid could possibly be even reversed when the chemicals are used against another species of aphid.

Factors influencing pesticide effectiveness

These factors can be grouped under four different headings, as shown below.

Pest organism

Species concerned. Certain species within a group (e.g. either Lepidoptera, or more specifically Noctuidae) may show markedly less susceptibility to a particular chemical than the others in the group. This is shown strikingly in the bollworm complex (Noctuidae) on cotton in parts of Africa.

Stage of organism. Both egg and pupal instars are biologically resistant stages designed to survive under adverse environmental conditions, and many (most) pesticides are ineffective against them. Conversely, a few pesticides may be particularly effective as ovicides.

Age of organism. With caterpillars, especially Noctuidae, the older stages, particularly fourth and fifth instars, are far less susceptible to most chemical poisons, even though at this time their food consumption is at a peak; the dose that would kill a second instar larva usually has no discernible effect upon a final instar larva. This situation also prevails so far as some other insects are concerned (Diptera, Coleoptera, etc.).

Development of resistance. From the first time an insect population is subjected to insecticidal action, selection for natural resistance is operating, and after a few years many species show noticeable resistance to that chemical (and other closely related chemicals usually). As resistance develops so the effectiveness of that chemical declines.

Chemical

Target success. In laboratory testing the target insect is typically sprayed directly, and so most application uncertainties are eliminated. However, with field crop applications the target insects are frequently not reached, due to their evasion, operator carelessness, insecticidal drift, inappropriate machinery or application equipment, incorrect timing, etc. At best, most field applications have a very low efficiency rating: usually only a few percent; the most efficient recorded has been aerial spraying of locust swarms (see page 123).

Persistence. This is by definition the efficiency over a period of time. Generally the organochlorine compounds were very persistent and remained effective for months often. Some carbamates are quite long-lived, but most organophosphorous

compounds are quite short-lived and their persistence is measured in weeks or even days. Persistence in the field is closely linked to the physical/climatic factors listed below, as they affect the natural rate of chemical *degradation*. The storage history of a chemical being used is of relevance, as sometimes chemicals may be stored for several years prior to sale.

Dosage. Variation in dose rate produces a corresponding variation in kill. In practical terms dosage is arrived at as a balance between cost/effectiveness and phytotoxicity. A low dosage gives only a small kill, but usually encourages resistance development; a very high dosage scarcely increases the kill above the usual level, but is likely to cause phytotoxicity.

Sometimes the ‘official’ dosage recommendations are not particularly clear; for example in the *Pesticide Manual* (1994) the uses for permethrin are given as ‘effective against a broad range of pests. It controls leaf- and fruit-eating lepidopterous and coleopterous pests in cotton at 100–150 g a.i./ha; fruit at 25–50 g/ha; vegetables at 40–70 g/ha; vines, tobacco, and other crops at 50–200 g/ha.’ For practical purposes it would be preferable that more specific local recommendations be made, and this is usually done by the local Ministry of Agriculture staff. The presentation of dosage recommendations may be complicated in that technical data are expressed as a weight/volume of active ingredient (a.i.; i.e. pure chemical) per area of application, or volume of spray, etc. Most pesticides are produced in several different concentrations and different formulations, so the a.i. for each has to be calculated prior to use. A very recent trend in some publications has been to express dosage in terms of *acid equivalent* (a.e.), which is reported to be the active ingredient expressed in terms of the parent acid! For practical purposes a simplified system of dosage recommendation may be preferable, especially for peasant farmers, when the actual amount of locally available formulation to be used can be stated.

In some rural situations, especially throughout the Third World countries, the level of understanding in the farming/smallholder community, of the basic principles of pest control, may be very low. Where understanding is minimal there is often a tendency for the farmer to apply a smaller dose than recommended to save on the costs. Where there is some understanding of pest control principles by the farmer, there is sometimes a tendency to increase the suggested dosage on the assumption that ‘more must be better’. In Europe and parts of Australia there has long been an inclination on the part of farmers to apply more pesticides, more heavily, and more frequently than actually needed; also many situations have been recorded where a farmer made appropriate pesticide application but then continued the applications long after the need had been removed. Present emphasis is for better communication, greater understanding by the farming community, and a more judicious use of pesticides generally.

Formulation. There may be some differences in effectiveness according to the precise mode of formulation, and also in respect to spray additives. Occasionally in spray mixtures there may be chemical incompatibility.

Cost. Some of the newer chemicals are expensive, and occasionally prohibitively so for smallholders and peasant farmers, especially for use on their food crops.

Availability. In the more advanced countries there is usually a large selection of pesticides available, as opposed to many Third World countries where often currency exchange problems restrict levels of imports, sometimes severely. However, some of the chemicals listed in this chapter are not universally available, as in Europe sales of Japanese chemicals and purely American chemicals are very limited, and *vice versa*, although many of the more useful pesticides are quite widely manufactured now throughout the world under licence from the company with the patent.

Local approval. Because of the hazards involved in the use of these chemical poisons, most countries now have local legislation to control the importation and/or use of the more toxic or ecologically damaging chemicals. For example, few countries now permit the import or use of parathion despite its effectiveness as an insecticide, because of its high mammalian toxicity, especially its dermal toxicity. Most European countries are likewise restricting the use of the organochlorine compounds, with a view to their eventual abandonment as suitable alternatives are found (and as resistance becomes more widespread and more total), but in the USA as a result of the activities of the EPA there has for several years been a total ban on the use of the organochlorine compounds.

Toxicity to bees, livestock and fish. Some compounds may be very effective entomologically, but their particular toxicity selective to pollinating bees, fish, etc., may restrict their use in certain situations. Thus in an area adjacent to intensive freshwater fishing it would be advisable to avoid the use of endosulfan with its very high fish toxicity. Similarly in parts of Europe where apiculture is a major industry it would be advisable to restrict the use of some of the compounds more dangerous to bees.

Climate/Soil

Temperature. At low temperatures the chemical may be relatively inactive (as will the insects of course), but at high temperatures chemical degradation is accelerated. In temperate situations repeated use of organochlorines typically resulted in a soil residue build-up over the winter period, but a fairly rapid degradation through the warm summer. Most tropical countries never experienced the alarming accumulation of DDT or dieldrin in the soils because the higher ambient temperatures throughout most of the year degraded the chemicals quite rapidly.

Moisture. High levels of soil moisture tend to accelerate chemical breakdown; but alternatively some chemicals do not work effectively if the soil is dry.

Rainfall. Heavy or persistent rainfall tends to wash off pesticides from the upper levels of plant foliage into the soil. This tends to be more of a tropical problem rather than temperate. Heavy rainfall will also cause chemical leaching into nearby water-collection systems.

Insolation. High levels of solar radiation (especially the ultra-violet component) greatly accelerate degradation of pesticides, but this is more a problem of the tropics rather than temperate regions.

Soil types. Some soil types, especially the peat (muck) types with a high organic content, may inactivate some pesticides by surface adsorption; dosages for such soils are usually doubled relative to those for mineral soils. Soils excessively acid or alkaline may affect pesticide performance and degradation rate. The importance of soil structure (as indicated by texture) in relation to pesticide performance is now becoming widely recognized and, for the first time in 1983, the MAFF *Approved Products for Earmers and Growers* had a section on 'The definition of soil types on labels of approved products' (pages 26–7).

Crop plants

Plant size. The usual aim when applying insecticidal sprays is for foliage cover, and clearly the size of the crop plants, spacing and plant density, will affect pesticide performance. If foliage density is great, then it may not be possible to reach the lower levels with a pesticide spray; some dense plants may have a leaf area index (l.a.i.) of 3.0 or even more. Leaf size and arrangement may also be important as many pests typically lurk underneath the leaves and may not be reached by insecticidal sprays delivered vertically from above. In many orchards and plantations, tree planting is arranged so as to permit spraying machinery access between the rows with nozzles pointing upwards to deliver the spray on to the undersides of the leaves.

Crop sensitivity. Some plants are unduly sensitive to certain chemicals, as is shown particularly by the 'sulphurshy' crops and varieties on which sulphur formulations should not be used. At very high dose rates most crops can be expected to suffer phytotoxicity; this adverse effect is often a reaction to the spray additives rather than to the pesticide itself.

Considerations in pesticide use

Efficient use of pesticides

To ensure accurate application the label should be read carefully *before* use, and the recommended doses, volumes and times of applications followed. With many of the newer, short-lived chemicals, dosage, placement and timing are critical. Attention should also be paid to maintenance of equipment, for defects such as faulty or worn nozzles can appreciably alter rates of application.

Compatibility of mixed products used in combined spray programmes is important. If no information is given on the labels consult the manufacturer or dealer. Wetting agents are sometimes used as additives to sprays for crops that are difficult to wet (e.g. brassicas, peas), but not all wetting agents are compatible with all proprietary formulations.

Taint and damage to plants are hazards to be avoided. Where chemicals are known invariably to cause damage to certain crops or varieties of plants, or if taint or off-flavours are produced in edible crops, this is mentioned under the specific chemical.

Pest resistance to pesticides. Pest resistance to chemicals is one of the major problems in agricultural entomology in all parts of the world now, and is ever increasing. Such cases arise in localized areas, or even on certain holdings, and may remain purely local for some time. Resistance does not usually develop until a particular chemical has been employed in that area for some considerable time (3–10 years). Sometimes resistance to one compound may be closely followed by resistance to other related compounds, e.g. one organochlorine compound and the others in the same group.

Information as to which major local pests may be exhibiting resistance to widely used insecticides can usually be obtained from the local Ministry or Department of Agriculture staff.

Natural control agents. It is very important that pesticide applications should not adversely affect existing natural control of the pest population. To this end, it is desirable that knowledge of the local predators and parasites of key pests be accumulated so that, whenever possible, existing levels of natural control may be maintained in addition to the artificial control measures that are being applied. Fairly obvious cases where extreme care should be taken are infestations of scale insects on trees, leaf miners, and sometimes the late stages of aphid infestations.

Storage of chemicals. Storage of chemicals is important; they should be kept in a dry place protected from extremes of temperature. Generally frost is more harmful to stored liquid formulations than is high temperature. Most formulations may be expected to be used for at least two years without loss of efficiency, but unsatisfactory storage conditions can impair stability and effectiveness.

Safe use of pesticides

All pesticides should be treated with care whether they are known to be particularly poisonous or not, and the following routine observed.

(1) Read the label, especially the safety precautions, carefully before use.

(2) Use all products as recommended on the labels and do not use persistent chemicals where there are effective, less persistent alternatives.
(3) Avoid drift on to other crops, livestock and neighbouring property and take care to prevent contamination of any water source, whether for drinking or irrigation purposes.
(4) Safely dispose of all used containers. Liquid contents must first be washed out thoroughly and the washings added to the spray tank. Packages containing powders or granules must be completely empty before disposal. Burn bags, packets and polythene containers. Puncture non-returnable metal containers (except aerosol dispensers) and bury them in a safe place. Bury glass containers or dispose of them with other refuse. On no account use empty pesticide containers for any other purpose.
(5) Return unused materials to store under lock and key.
(6) Clean any protective clothing used, and wash exposed parts of the body thoroughly when the job is completed.

Particular attention should be paid to the paragraph headed ‘Caution’ in the pesticide section of this chapter. It indicates:

(1) whether the chemical is particularly poisonous; if so, certain protective clothing should be worn.
(2) whether there are any special user risks involved, even if not very toxic, such as irritation to the skin. Some protective clothing should be used with these chemicals, and their labels should be consulted for guidance.
(3) what precautions should be taken to ensure that unacceptable residues do not remain on edible crops at harvest. Where appropriate, the time at which a chemical may be applied is shown and also the minimum interval that must be observed before last treatment and harvest.
(4) whether there are risks to bees, livestock, fish or other wild life. In the case of bees, the degree of risk is given as *dangerous, harmful* and *safe* (see following section).

Fish are susceptible to many chemicals, and great care must be taken to prevent contamination of ponds, waterways and ditches with chemicals or used containers.

Toxicity to bees

Dangerous: highly toxic to bees working the crop or weeds, at time of treatment, toxic for 24 hours or more.

Azinphos-methyl	HCH
Bendiocarb	Heptenophos
Carbaryl	Lead arsenate
Chlorpyrifos	Methomyl
Cypermethrin	Mevinphos
Deltamethrin	Monocrotophos
Demeton-*S*-methyl sulphone	Parathion
Diazinon	Permethrin
Dichlorvos	Phosphamidon
Dieldrin	Phoxim
Dimethoate	Pirimiphos-ethyl
Endrin	Pirimiphos-methyl
Ethoate-methyl	Propoxur
Etrimfos	Quinalphos
Fenitrothion	Triazophos
Formothion	

Harmful: toxic to bees working a crop at the time of treatment, but not hazardous if applied when bees are not foraging.

Acephate	Methidathion
Bromophos	Menazon
DDT	Nicotine
DDT with malathion	Omethoate
Demephion	Oxydemeton-methyl
Demeton	Phosalone
Demeton-*S*-methyl	Sodium monochloroacetate
Endosulfan	Tetrasul
Malathion	TDE
Mecarbam	Thiometon
Mercury	Vamidothion

Safe (now referred to as ‘offering minimal hazard’):

Aldicarb (granules)	Mephosfolan (soil drench)
Binapacryl	Phorate (granules)
Dicofol	Pirimicarb
Diflubenzuron	Quinomethionate
Dinocap	Rotenone
Disulfoton (granules)	Schradan
Ethiofencarb (granules)	Tetradifon

With a number of pesticides in current use there is no precise information readily available as to their toxicity to bees.

Chemicals included in the Health and Safety (Agriculture) (Poisonous Substances) Regulations (1975) (UK)

These regulations are laid down in the Statutory Instrument No. 282 (1975), and they require any user of certain chemicals in the UK to observe certain precautions in their use. This section is included here as general information to indicate which of the pesticides are most dangerous, and the type of precautions required for their safe application. However, it must be remembered that only chemicals at one time ‘approved’ are on this list; several of the chemicals listed below are not at present (1983/4) approved, but they were on former lists.

Part I substances

Chloropicrin
Dimefox

Full protective clothing, e.g. rubber gloves and boots, respirator, and either an overall and rubber apron or a mackintosh when preparing the diluted chemical. The respirator may be dispensed with when the diluted chemical is applied to the soil.

Part II substances

*Aldicarb
Carbofuran
Disulfoton
*DNOC
*Endosulfan
Endrin
Fonofos
Mephosfolan
*Methomyl
*Mevinphos
Oxamyl
Parathion
Phorate
Schradan
*Thiofanox
Thionazin

Full protective clothing, which includes rubber gloves and boots and, either a face shield or dust mask, and an overall and rubber apron or a mackintosh; or a hood, or a rubber coat and sou'wester, depending on the operation being performed. A respirator is required when applying aerosols or atomizing fluids in glasshouses.

When the substances are used in the form of granules certain relaxations in the protective clothing requirements are allowed.

Part III substances

Amitraz
*Azinphos-methyl
*Chlorfenvinphos
*Deltamethrin
*Demephion
*Demeton-S-methyl
*Dichlorvos
Ethion
Heptenophos
*Methidathion
Nicotine
*Omethoate
*Oxydemeton-methyl
Phosphamidon
Quinalphos
*Thiometon
*Triazophos
*Vamidothion

Rubber gloves and face shield when preparing the diluted chemical.
Full protective clothing, i.e. overall, hood, rubber gloves and respirator, is needed however when applying aerosols or atomizing fluids in glasshouses.

*These pesticides are included on the *Poisons List* (1972), and the *Poisons Rules* apply general and specific provisions for the labelling, storage and sale of these chemicals (as per *Approved Products – 1983*).

The more widely used insecticides and acaricides currently available for crop protection[†]

The data presented here are mostly derived from Tomlin (1994), the 7th ed. by Worthing (1983), MAFF (1983) and from the pesticide data sheets provided by the various chemical companies (Bayer, Shell, ICI, Ciba-Geigy, etc.).

Insecticides in current use mostly fall into several different categories, according to their chemical structure and mode of action, but some are unfortunately intermediate in chemical structure, or else somewhat anomalous, and do not lend themselves to easy categorization. For teaching purposes it is desirable to be able to distinguish between these basic groups. However, in this book, for practical purposes the following basic types of insecticides are recognized: chlorinated hydrocarbons, substituted phenols, organophosphorous compounds, carbamates, miscellaneous compounds, natural organic compounds, organic oils, biological compounds, and insect growth regulators. Clearly some of these groups could equally well be subdivided and their arrangement here is somewhat arbitrary.

Many pesticides are sold as mixtures to be used against a pest complex.

Chlorinated hydrocarbons

These compounds are often referred to as the 'organochlorines' and collectively they are a broad-spectrum and very persistent group, which usually kill both by contact and as stomach poisons. Generally they are more effective against insects with biting mouthparts than the sap-suckers. Because of their persistence they get taken up in food chains very easily and accumulate in the body fat of the vertebrate predators at the apex of the food chains. Under normal conditions this build-up in the body fat may not affect the animal, but in times of starvation, when body fat reserves are being utilized, the amount of pesticide released into the blood may be critical or even fatal. Most countries in Europe and N. America are in the process of restricting the use of chlorinated hydrocarbons where *suitable alternatives* are available, because of the long-term contamination dangers to the environment. It can also be observed that in most of these countries the major pests have already become, or are now becoming, resistant to the organochlorine compounds, and so their period of utility is ending. In some cases, though, suitable alternatives are not readily forthcoming.

† The insecticides and acaricides used mostly for protection of stored products, domestic use, and against medical and veterinary pests, are not included in this list, neither are chemicals used solely as nematicides, fungicides, etc.

In the tropics chemical degradtion often proceeds quite rapidly due to the high daily temperatures and also high level of insolation and sometimes torrential rain, so generally there is not the same pollution problem as in northern regions. Europe and the USA may not be manufacturing DDT and the other OCs any more but there were large quantities in store and they were sold abroad, especially in Africa and tropical Asia. By 1991 DDT was still being produced in Italy, India, Indonesia and Mexico, as reported by UNEP. The countries that still permit the import of DDT include Bhutan, Bolivia, Ethiopia, Guinea, India, Kenya, Malaysia, Mauritius, Mexico, Nepal, Philippines, Sri Lanka, Sudan, Tanzania, Thailand, Venenzuela and Vietnam. In 2004 the global treaty on Persistent Organic Pollutants made the prohibition of the OCs global - except for a clause allowing DDT manufacture for use in disease control; but some African and Asian countries have continued to use it for crop protection. In 2006 the WHO endorsed the use of DDT for malaria control.

The organochlorine compounds may be subdivided into several groups: the three most commonly used groups are represented by DDT, HCH and aldrin (cyclodienes). Despite the structural differences between the subgroups they do possess several characteristics in common: they are chemically stable, have a low solubility in water, moderate solubility in organic solvents and lipids, and a low vapour pressure. The properties of stability and solubility make most of the group very persistent. They also produce similar physiological responses in the insects.

The solubility of DDT in lipids enables the poison to penetrate the insect integument quite readily (as opposed to slow penetration through animal skin). This difference in penetrative ability would account for its selective toxicity to insects. Cuticle thickness does not seem to greatly influence the susceptibility of insects to DDT, although it may penetrate more readily through the flexible intersegmental membranes. Dissolution in the epicuticular wax is apparently the essential prerequisite to toxic action. Penetration rate of the poison increases with temperature, often nearly doubling for a 20°C rise in temperature. The precise mode of action of these poisons on the insect is not fully understood.

Pesticides (Chemical control)

Pesticides are chemical poisons that kill pest organisms. Some of the very toxic fumigants kill almost all biological organisms, but most poisons are only effective against certain groups. For example, insecticides kill insects; herbicides kill weeds; fungicides kill fungi; bactericides, bacteria; rodenticides, rodents etc. Some major pesticides in current (or recent) use are listed below, but fungicides and bactericides are not included. Rodenticides are referred to in Chapter 10. For further information, see Appendix 1, pp. 415–437.

Some major pesticides in current or recent use

Chlorinated Hydrocarbons (= Organochlorines) (= OCs)
The first of the 'modern' insecticides, whose development started with DDT in 1940. Broad-spectrum; persistent; stomach and contact poison.

- DDT group - DDT
- BHC group - BHC
- Cyclodienes - Aldrin, Dieldrin, Endosulfan etc.

Most are now banned in many countries because of environmental damage, and pest resistance is very widespread. A total of 14 compounds are known.

Organophosphorus Compounds (= OPs)
Developed as nerve gases (World War II); very poisonous; contact and systemic poisons; high mammalian toxicity; short-lived; some quite specific; action is inhibition of acetyl-cholinesterase – thus a nerve poison.

- Bromophos Dimethoate Malathion
- Chlorpyrifos -methyl Etrimfos Pirimiphos-methyl
- Diazinon Fenitrothion Tetrachlorvinphos
- Dichlorvos Cyanophos
- Dickotophos Chlormephos etc.

About 70 compounds have been used as insecticides.

Carbamates
Also act as anti-cholinesterases; more broad-spectrum of activity; developed because not so toxic to vertebrates.

- Bendiocarb Alanycarb Aldoxycarb Carbosulfan Benfuracarb etc.
- Carbaryl Methiocarb Propoxur

About 30 compounds being used as insecticides; most are fungicides and herbicides.

Miscellaneous compounds
Inorganic salts and organic fumigants. Amongst earliest compounds used.

- Copper acetoarsenite (Paris Green) Aluminium phosphide
- Lead arsenate Carbon tetrachloride
- Lime sulphur Ethylene dibromide
- Mercurous chloride Methyl bromide

Natural organic compounds
Mostly from plants with compounds toxic to insects.

- Nicotine - from Tobacco; very poisonous; fumigant and contact action.
- Neem - foliage and seeds have insecticidal properties (Azadirachtin).

- Rotenone - from roots of *Derris* spp.; powerful fish poison.
- Pyrethrins - from flowers of *Pyrethrum*; rapid knock-down; used with synergists; only poisonous to insects; very safe to use; rapid degradation in sunlight.
- Pyrethroids - new synthetic insecticides; broad spectrum, persistent, but some vertebrate toxicity. Eight or more compounds regularly used, but 35 are available. (Permethrin, Cypermethrin, Bioallethrin, Acrinathrin, Allethrin, Bifenthrin, Cyfluthrin, etc.

Organic oils (= Hydrocarbon oils)

- Tar oils - heavy, dark, toxic, phytotoxic; 'winter washes'; creosote; wood preservatives.
- Kerosene - of great antiquity; mostly used as fungicide and herbicide (T.V.A.)
- Petroleum oils - distilled, lighter (mineral and white oils).

Biological compounds

- Antibiotics and entomophagous fungi–*Beauveria* spp.
- Bacteria - *Bacillus thuringiensis* (Bth) – caterpillars killed.
  - *B. popilliae* – Japanese Beetle Milky Disease, Kills beetles.
- Viruses - most effective against caterpillars and beetles.

Insect Growth Regulators (IGR) (including *juvenile hormone analogues* (JHA) and *chitin synthesis inhibitors* (CSI))
Chemicals with hormonal properties that disrupt insect physiological development.

- Methoprene (JHA) – prevents metamorphosis.
- Diflubenzuron etc. (CSI)
- Chlorfluazuron (CSI)

There is a total of about 50 insecticides that do not fall into the above categories (Tomlin, 1994).

9 *Major tropical crop pests*

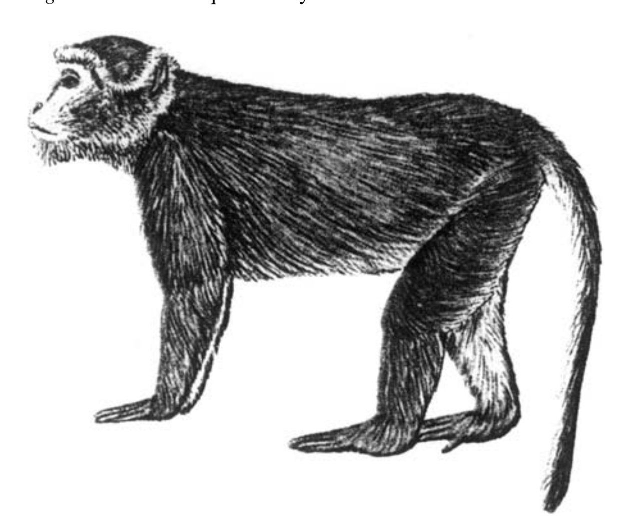
Vertebrata

Class Mammalia

MAN Sad to say, but theft has become a major problem in many rural areas and pilferage is widespread. High value fieldcrops and fruit are especially vulnerable, as are grain stores. One result is that seed stores are kept inside homes and many grain stores are dug in the floors of the huts.

Several species
Common Name Monkeys
Family Cercopithecidae
Hosts Edible crops of all types (grains, fruit, vegetables, roots) may be eaten, as well as cotton bolls, coffee berries and cocoa pods.
Damage Edible parts are stripped and eaten, roots may be dug up, and physical damage to the plants may be extensive. Young palms (oil and coconut) may be destroyed, and young coconuts opened and eaten.
Pest Status Occasional pests in many locations, but they can be locally very serious.
Life History These primates are gregarious and live in large family groups, under the leadreship of a dominant male who can be very aggressive. Body weight is usually 6–7 kg. They are omnivorous in diet but feed mostly on plant material Some food materials are carried away to be eaten at leisure. The monkeys are partly arboreal but the baboons more ground dwelling.

Fig. 9.1. Adult Macaque monkey S. China.



Distribution The main pests are Old World species.
Macaca spp. (Macaques) Several species are found throughout tropical Asia, up to China and Japan (Fig. 9.1).
Cercopithecus spp. (Guenons, Vervets, Grivets, etc.) An Africa, genus with a dozen species of different colourations (Fig. 9.3).
Resbitis spp. (Langurs) Mosrtly found on the Indian subcontinent and Malaya.
Papilio spp. (Baboons) A dozen species are found throughout Africa; they are larger than monkeys, more terrestrial in habits, and can be very aggressive.
Control These are intelligent animals and very difficult to control. Usually the most effective method is to drive marauding troops away with noise and human presence, sometimes shooting is necessary.

Fig. 9.2. Young Coconut damaged by Macaque monkey.



Fig. 9.3. Adult Vervet monkey, Uganda.

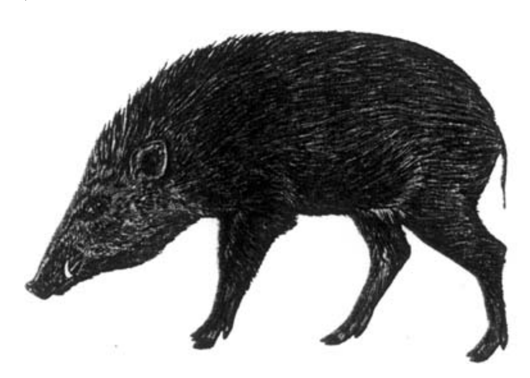


Several species
Common Name Wild Pigs
Family Suidae
Hosts A wide range of edible plants are eaten, but preference is shown for root crops and tubers.
Damage The roots and tubers are dug up with snout at night and eaten on the spot. Digging holes can be quite extensive as they feed gregariously.
Pest Status Occasional pests, often serious in gardens which are raided at night; some damage to oil palm plantations is recorded.
Life History They live in small family groups in forest or scrubland, and forage for food at night. Full grown pigs weigh 100–150 kg and have a shoulder height of 80 cm. They are totally omnivorous in diet. Males have prominent tusks that are quite conspicuous. Body colouration is dark grey-brown, but the young are striped pale and dark brown.
Distribution
Sus scrofa (Wild Boar) Found throughout Europe and tropical Asia as a number of different subspecies (Fig. 9.4).
Sus barbatus (Bearded Pig) A species endemic to S.E. Asia.
Potamochoerus porcus (African Bush Pig) As the name indicates this is an African species and often is a dark reddish colour.
Control With field crops the sporadic raids are very difficult to prevent but garden plots can be fenced to prevent access.

Ungulates/Bovines (Deer, etc.)
Families Bovidae and Cervidae
Hosts A wide range of herbaceous and some woody plants are browsed by an equally wide range of antelopes (Africa), deer (Asia) and goats, but damage is very localized and seldom serious.

But unrestricted domestic goats can be devastating to growing plants and small woody plants are completely killed.

Fig. 9.4. Adult Wild Boar, S. China. Juvenile Boar.



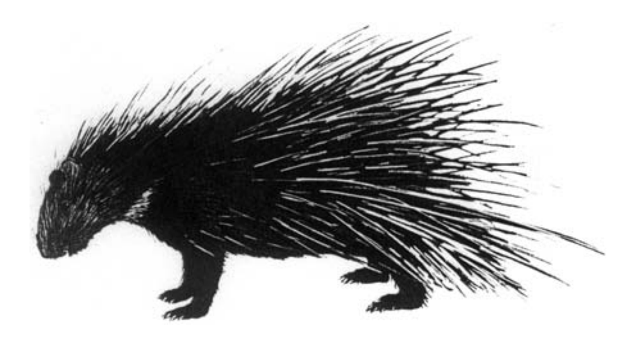


Order rodentia

A very large group, completely worldwide in distribution but most abundant in the tropics. They are all herbivorous with large incisors that grow continuously and a conspicuous diastema showing the absence of canines. Some species have enormous reproductive potential and population outbreaks can be common, especially in parts of Asia and Australia.

Hystrix spp. (Fig. 9.5)
Common Name Porcupines
Family Hystricidae
Hosts Various vegetable and root crops, especially sweet potato, are most at risk; young oil palms may be killed.
Damage The plants are gnawed and eaten, but sweet potato tubers have first to be dug up, this is all done at night. Young oil palm plants are eaten at their base.

Fig. 9.5. Adult Porcupine (*Hystrix* sp.), S. China.



Pest status Occasional pests which can be very damaging to garden plots and oil palm plantations, particularly the seed beds.
Life history Rather surprizingly porcupines have an underground nest burrow where they sleep and breed. They usually have only two young at a time and so are never abundant locally. In N. America there are species totally arboreal in habits.
Distribution There are several species of *Hystrix* found throughout Asia and Africa – very widespread in small numbers. Some other species are now placed in other genera including a few that resemble spiny-haired rats.
Control Seldom really needed but garden plots can be fenced.
Cane Rats (*Thryonomis* spp. - Echimyidae) are related to Porcupines and occur in tropical Africa where they are hunted for their flesh and known as Edible Rats. In West Africa some are reared commercially as human food.

Callosciurus spp.
Common name Tree Squirrels
Family Sciuridae
Hosts A range of fruit trees and plantation crops are attacked, especially papaya, oil palm and cocoa where the fruits are eaten.
Damage The fruits are eaten, and all green parts of the plant body may also be eaten. They are entirely herbivorous but occasionally they take insects and birds' eggs. On oil palm the feeding damage is identical to that of rats.
Pest status Widespread and often locally common, but usually minor pests, easily frightened by human activity. They are diurnal in habits, or crepuscular.
Life history They nest in tree holes or sometimes make an aerial nest of twigs and leaves. Litter size is uaully 2–4 and the reproductive potential is low so they are not as serious pests as rats. Total length is 30–40 cm, half of which is the bushy tail; body colour varies considerably.
Distribution In S.E. Asia there are about a dozen species of squirrel placed in this genus; they range from China to India and Borneo. This region is renowned for the radiation shown by the squirrels – there are Ground Squirrels, Tree Squirrels, Flying Squirrels, and Giant Squirrels; some species are confined to mountain ranges, and others are lowland species, but only a few are pests. Ground Squirrels are quite common in India and also parts of Africa, but are at most only minor pests.
Control Control is seldom required as their numbers are not great and their reproductive potential is low.

In S. India several species of *Funambulus* are serious pests of plantation crops (especially oil palm and coconut), and others are pests of orchards and gardens in the north and central plains (see Parshad, 1999).

Fig. 9.6. Adult Tree Squirrel (*Callosciurus* sp.) S. China.



Fig. 9.7. Squirrel feeding damage to papaya fruit; Sarawak.



Tachyoryctes ankoliae
Common name Common Mole Rat
Family Muridae
Hosts The roots of many different crops and plants are eaten underground, and green plants may be collected and taken into their burrows.
Damage They have an extensive underground tunnel system, marked on the surface at intervals by characteristic mole-hills. The mole rats eat plant roots underground, but do emerge on to the surface at night where they cut plant foliag to eat. Damage to crops and growing plants can be locally serious, especially on coffee in Kenya.
Peast status A widespread pest in tropical Africa but usually found in highland regions in small numbers, and only occasionally doing serious damage. The mole-hills are very conspicuous.
Life history Mole rats live in deep undergound tunnel systems and they feed mostly on plant roots. The adult is a plump, short-tailed rate about 20 cm long, with soft fur. Ears and eyes are very reduced and their sight is poor but have good hearing and are sensitive to vibration. The incisors are very large and are used for digging.

Fig. 9.8. Adult Mole Rat, body length 15 cm; Ethiopia.



Fig. 9.9. Close-up of Mole Rat showing large incisors.



Distribution This and a couple of other species are found throughout tropical Africa and in parts of southern Asia, in short grass areas.
Control Control is seldom required but can be affected using tunnel traps and fumigation of the tunnel system.

Fig. 9.10. Mole Rat mole-hills, Alemaya, Ethiopia.

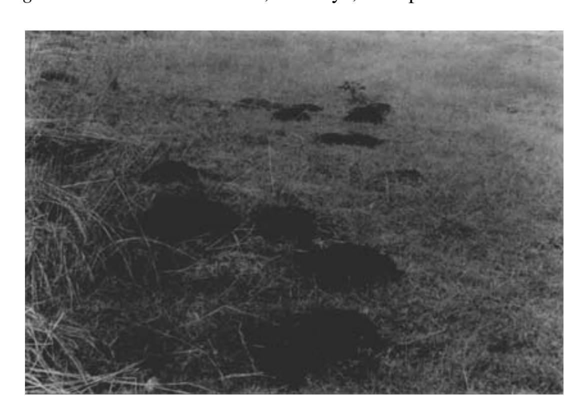
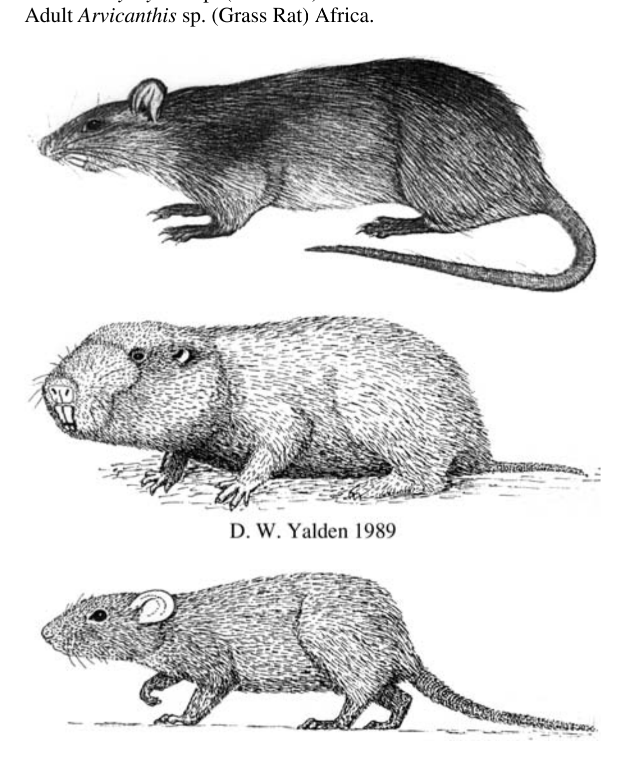


Fig. 9.11. Adult *Bandicota indica* (Bandicoot Rat); body length 28–32 cm and tail 18–24 cm.
Adult *Tachyoryctes* sp. (Mole Rat) Africa.
Adult *Arvicanthis* sp. (Grass Rat) Africa.



Rat pests

Throughout the world, but especially in the tropics and subtropics rats are particularly serious pests both of certain field crops (oil palm, coconut, rice, etc.) and of stored products (grains, pulses, cassava, copra, etc.) especially in on-farm stores. A number of different species are found as field rats, with differences bewteen Africa, India, S.E. Asia, and S. America. In tropical Asia and Africa more than a dozen species of rats are found in fields, swamps, and wooded areas and some are recorded as pests, especially *Arvicanthis* spp. (Grass Rats) in Africa, *Bandicota* spp. (Bandicoot Rats) in India and S.E. Asia, and *Oryzomys* spp. (Rice Rats) in S.E. Asia.
The stored products pests are mostly species of *Rattus* some of which are now quite cosmopolitan in distribution.

Control of rats and mice pests

Natural enemies. For both *Rattus* species, the main predators in the tropics are snakes – ground snakes such as the cobras (*Naja* spp.), rat snakes (*Pytas* spp. etc.; Colubridae) for *R. norvegicus*, and the arboreal cat snakes (*Boiga* spp.) for *R. rattus* especially. But throughout the tropics, the local people invariably have a deep and unreasonable fear of all snakes, and kill them whenever possible. And in some countries, India for example, snakes are killed for their skins, and there are thriving local industries. The result is a serious depletion of urban snake populations. In addition, other predators such as civet cats (Viverridae), mongooses and other carnivores are killed by the local villagers. The end result is a greatly enlarged urban rat population. A recent FAO survey in India concluded that there were six urban rats for every human being in the country.

In Ethiopia, local cats killed the common rats (*Rattus rattus* mostly) without hesitation, and the feral cats then ate them. The feline value in rat control was widely appreciated by the local villagers, and most huts had a hungry cat in residence; this practice had a major suppressive effect on the local rat population.

In Malaysia a recent development has been the installation of nest boxes for Barn Owls (*Tyto alba* sspp.) in the oil palm plantations where the owls prey on the *Rattus rattus*. This scheme has proved so successful that it is being introduced into other oil palm growing areas.

Control. A point that has been raised in several recent rodent control publications relates to the vast reproductive potential of these main pest species. In many pest control exercises, a kill of 90% rates a chemical pesticide as being effective commercially, and in some pest management programmes, an insect population reduction of 90% is adequate for control purposes. But with *Rattus norvegicus* and the other domestic rodents, their reproductive potential is so great that a survival rate of 10% would enable the population to re-attain its original size within a matter of only months. A population survival rate of 5% is basically too much to leave uncontrolled, and in many situations with isolated food stores, it is probably worthwhile to attempt a rodent eradication programme.

Physical and cultural control. General sanitation methods include removal of additional food sources, the packing of produce into containers, keeping the containers off the floor if possible, removal of garbage from the proximity of food stores. The building should be rat-proofed by constructing it of materials that rats cannot bite through (i.e. concrete, brick, sheet ashestos, sheet iron etc.). Fine mesh wire netting or metal gauze should be placed over ventilation holes. The sites where pipes pass through the walls and eaves of buildings are especially vulnerable, and access from nearby sewers and drains should be prevented. Buildings on stilts, or small on-farm containers on legs, should have rat guards fitted to the legs. But in the least developed countries, such recommendations are not easily followed because of the costs and the availability of materials. It should be remembered that rats have poor vision, but keen senses of smell, taste, touch and hearing.

Trapping. Rats are not easy to trap, although if care is taken to disguise human smells (for example, in Ethiopia, by rubbing a cut onion bulb over a baited snap trap), such traps can be very effective. Traps should be tethered by a string in case the rat is not killed, and, because they forage so widely, traps should be spaced well apart. Snap traps are not expensive, and will work for years. Rats are nervous of new objects and new foods, and pre-baiting may be necessary for a few nights before the traps are set (this certainly applies to the use of poison baits).

Tracking powders. These rodents are not so successfully attacked using tracking powders as are mice, and DDT was never effective; but sodium fluorosilicate is said to be effective, and valone is used.

Poisons. The basic plan is to mix a poison with an attractive bait material to entice the rats to feed (Figure 10.5). Any fast-acting acute poison quickly causes the animals to become bait shy (same as trap shy). The earliest poisons were inorganic salts of arsenic and the like. But in the 1950s the anticoagulant poisons were discovered. Their action is insidious with no manifest symptoms of poisoning, and these chemicals were very successful. However, after some years of repeated use, many rat populations have built up resistance to many of the earlier anticoagulants, but new chemicals and formulations are being developed. Liquid baits are sometimes effective, especially in dry regions where water is scarce. Otherwise, food baits are most widely used, based on grain, oatmeal, meat, fish, fishmeal, fruit or other types of vegetable matter. Any type of human food can be used, and local preferences may be shown; for example, in Ethiopia onions are used very widely in local cooking, and it is said that *Rattus rattus* is attracted by this odour – and it appeared to be true. Pre-baiting for a few nights with the bait material

alone is always recommended, especially if acute poisons are being used. Acceptance of new objects, such as a trap or a bait, with most rat populations typically takes several days, and for the shyest individuals it can take 10 days in experiments, even with a long-familiar food. Additives such as groundnut oil improve the acceptability of most baits. For tree baiting, the mixture is compressed into a block, often with wax added, and the block is nailed to the palm trunk where the rats run. For such exposed baits, a waterproofing additive is vital.

Poison grain baits are often coloured bright red as a safety measure. Acute poisons are one dose chemicals, and are still quite widely used in many tropical countries. Chemicals being used include strychnine, arsenic salts, zinc phosphide (sodium fluoroacetate), red squill, and norbormide.

The different rodenticides have different levels of general toxicity, and although often selective to *Rattus*, they do vary in toxicity according to the species of rat, and sometimes even to the race; in addition, there is the problem of the development of resistance to certain poisons by local rat populations.

Chronic, slow acting, multiple dose poisons are the anticoagulants, which cause the rats to bleed to death internally. Small, repeated doses are necessary over a period of time (a few days) to kill the rats, although some newer compounds can kill after a single feed – death occurs after a few days. The first chemical with anticoagulant properties developed as a rodenticide was warfarin. Now the list is quite extensive, and includes brodifacoum, bromodiolone, chlorophacinone, coumatetralyl, difenacoum, fumarin, pindone and others. Shell have recently publicised their new anticoagulant rodenticide, flocoumafen (‘Storm’), and claim that it is very effective, giving control levels of 95 per cent in field trials in S.E. Asia; and they say that a single feed is sufficient since the active ingredient is highly potent.

Fumigation will, of course, kill any rodents present in the produce at the time, and if the underground nest system of *R. norvegicus* can be clearly established, it can be sealed and flooded with poison gas (methyl bromide, phosphine etc.).

Recent studies in S.E. Asia showed that for large rural food stores with a serious rat problem, the most effective approach was an integrated one whereby traps were used in runs outside the stores, the stores were carefully maintained physically, and poison baits were used both outside and inside the stores, and gas was used down the holes. Since rats are both intelligent and very nervous (shy), they are unlikely to succumb in large numbers to any one particular method of control.

For centuries, man has relied heavily on the use of poisons for rat control in domestic situations, but so far it is a moot point as to who is winning this war. The two main problems are the intelligence of the rats and their ability to learn, and the speed with which they can develop resistance to the poisons.

Rodenticides can be classified into three separate generations, as follows:

1st generation poisons (acute poisons)

arsenic salts	}	
strychnine	}	80% kill the usual maximum
zinc phosphide	}	
red squill (scilliroside glycoside)	}	
norbormide	}	
cholecalciferol	}	

2nd generation (anticoagulant Rodenticides)

warfarin (& prolin)	}	
	}	
chlorophacinone	}	90% kills
diphacinone	}	achieved,
coumatetralyl	}	but resistance
coumaturyl	}	has developed to all

3rd generation (2nd generation anticoagulants)

difenacoum
brodifacoum - single dose effective
bromadiolone
flocoumafen - Shell claims 95% kill

(See Gorham (1991); pp. 426–433; and Parshad (1999))

Although *Rattus rattus* and *R. norvegicus* are the most serious and most widespread international rat pests of stored foodstuffs, there are others. In each part of the world there are field rats of different species, and most of these do occasionally invade on-farm field stores, and sometimes regional stores, and serious damage has been recorded. These species include:

Arvicanthis spp. (Grass rats) Africa
Bandicota spp. (Bandicoot rats) India, S.E. Asia to China
Mastomys natalensis (Multimammate rat) Africa
Nesokia spp. India
Oryzomys spp. (Rice rats) several important species are pests in Indonesia, Philippines and other parts of S.E. Asia.

Rattus rattus complex

Common Name Black Rat (Roof Rat; Field Rats; Ship Rat; etc.)

Family Muridae

Hosts Known worldwide as the Ship Rat, this is very common in ports, many cities and major urban areas where they feed in food stores. They are arboreal animals and very agile climbers. In S.E. Asia a major pest of oil palm and coconuts; they several subspecies here show different host preferences.

Damage Fruits are eaten *in situ* leaving characteristic chisel-like feeding scars. These are quite different from bird beak marks, but are identical to squirrel damage. Small ripe fruits may be carried away to eat at leisure. Palm seedlings may be eaten and killed. Gnawed young coconuts are killed and fall prematurely. The main damage to oil palm is the eating of the kernals – this is the major pest of oil palms in S.E. Asia.

Pest status The major pest of oil palm throughout S.E. Asia, and can be a serious pest of coconut. Some species are important domestic pests throughout S.E. Asia and others are pests of field crops. Their diet is omnivorous but basically frugivorous.

Life history Nests are constructed in the oil palm crowns, and in piles of debris on the ground, and 3–10 young are reared at a time. They become sexually mature at 3–4 months – thus one pair can produce 500 offspring in a year. This reproductive potential makes them very serious pests in locations where food is abundant. Body colour is dark grey/brown, or sometimes black, with a pale belly, and the long semi-prehensile tail is characteristic of arboreal species. Adults weigh about 0.25 kg and are medium-sized rats.

Distribution It appears that S.E. Asia is the centre of evolution for *Rattus rattus*, and it has spread throughout the world via shipping routes. Locally it exists as several distinct subspecies and also several closely realted species, including *R. tiomanicus* (Malayan Wood Rat), *R. argentiventes* (Rice-field Rat), and *R. annandalei* (Singapore Rat). In Africa *R. natalensis* is the Multimammate Rat and its white feet and white belly are characteristic – it is both a domestic pest and a crop pest. In S. America several species of *Rattus* are serious pests of paddy rice.

Control For control of rat and mouse pests see pages 120–121.

Fig. 9.12. Adult Black Rat from Hong Kong.

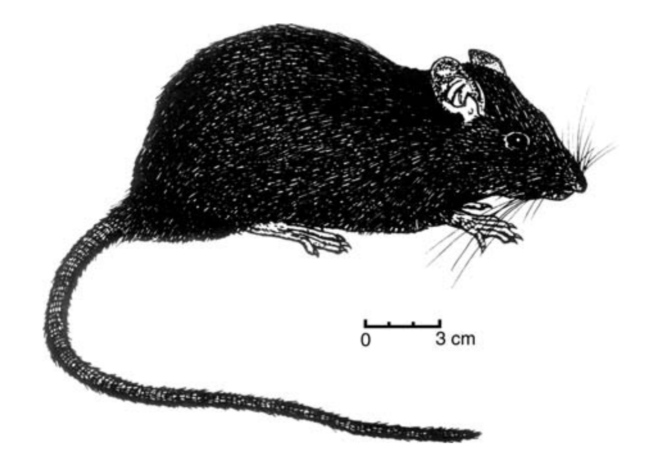
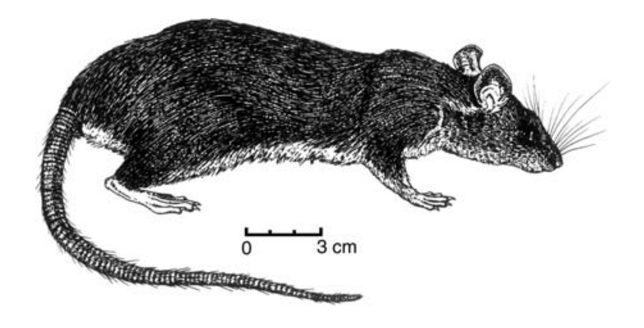


Fig. 9.13. Young coconut damaged by rat feeding; Sarawak.



***Rattus norvegicus* (Berkenhout)**
Common Name Norway Rat; Brown Rat (in Europe the Common Rat)
Family Muridae
Hosts An omnivorous pest with a diet much like human, but including garbage. In temperate regions commonly found in sewerage systems. In the tropics some crops are damaged in lowland locations but most damage is done in food and produce stores and domestic premises,
Damage Direct damage is done by eating the produce, fruita and grains often being preferred. In direct damage is done by contamination with faeces, urine and hairs (important for export crops).
Pest status A major domestic pest and damaging to some crops in the tropics.
Life history Adults are large heavy rats, up to 0.5 kg, with body length 19–28 cm and tail 80–100% of body length. Tail is not at all prehensile and this is a ground dweller. Colouration is typically grey/brown above with pale grey belly. They often live in colonies with subterranean breeding tunnels and runs to nearby water sources for drinking. They are usually nocturnal but can be seen in daylight. They reach sexual maturity in 3–5 months and produce 4–7 litters during their one year of life, each with 8–12 young, so their reproductive potential is enormous. A redent FAO survey in India estimated 6 rats for each person.
Distribution Now completely worldwide and on most oceanic islands. In the tropics mostly found in port cities and their environs, seldome in highland regions.
Control See pages 120–121.

Fig. 9.14. Rattus norvegicus (Brown Rat) from Hong Kong.



***Mus musculus* (Linn.)**

Common name House Mouse

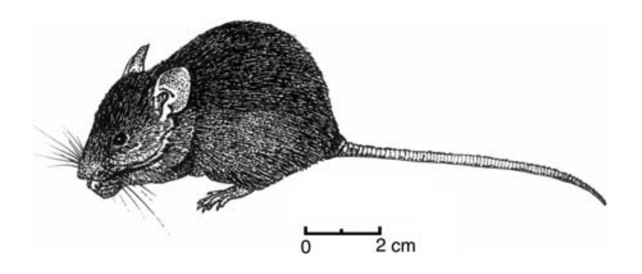
Family Muridae

Hosts These mice eat more or less the same foods as Man, and are more domestic pests than field pests. In parts of Australia there are regular population outbreaks of mice and grain stores, and some ripe cereal crops, can be completely over-run by thousands of mice, but generally such outbreaks are rare.

Damage As with rat instations there is direct damage by the eating of the produce and grains, and indirect but contamination with urine, faeces and hairs. Grain for export thus contaminated can be rejected. Mice consume less food than rates, but do a lot of gnawing and nibbling thus causing widespread light damage.

Pest status In produce stores and domestic premises mice are common pests but do not often cause serious damage. Grain for export can be rejected because of the presence of mouse hairs.

Fig. 9.15. Adult Asian House Mouse (*Mus musculus castaneus*; body length 70–90 mm.



Life history Mice become sexually mature in 2–3 months; the number of young usually 5–6 but 12–15 has been recorded. Some females in captivity have produced 100 year per year. The population irruptions that occur do not follow any discernable pattern (unlike the 4-year cycle of Field Voles (*Microtis* spp., Lemmings, etc.). Nests may be underground, or in plant debris, or crevices of various types.

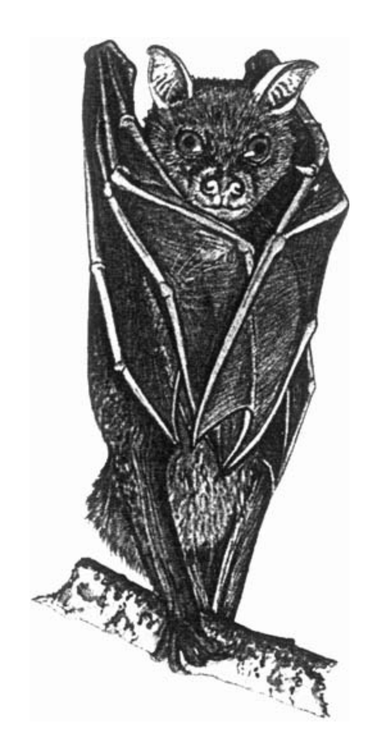
Distribution *M. musculus* occurs as a series of subspecies and races in a worldwide pattern – some races are more rural and others more domestic. Temperate Field Mice are placed in the genus *Apodemus*, but in warmer regions some Field Mice are placed in other genera by some taxonomists but others prefer to use the genus *Mus* (*sensu lato*).

Control Field Mice generally do not need control measures as their damage is slight; farm cats are usually sufficient. However they can be more easily trapped than rats as they are less ‘shy’.

Order Chiroptera; Sub-order Megachiroptera
Common name Fruit Bats
Family Pteropidae

A number of species are found throughout the tropics, ranging from the giant *Pteropus* (Flying Fox) with its wingspan of nearly one metre down to *Cynopterus* (Dog-faced Fruit Bat) of S. China with its 35 cm wingspan (Fig. 9.16). In Africa the most widespread species is the Yellow-haired Fruit Bat (*Eidolon* spp.) a large species that makes spectucaular communal roosts in eucalyptus and other large trees. They roost communally hanging upside down in tree foliage during the day and forage for fruit at night. Their natural food is basically ripe wild figs (*Ficus* spp.) but they will readily take ripe cultivated fruits (bananas, papaya, avocado, quava, etc.). Prompt harvesting of ripe fruits will minimize the depravation of fruit bats as well as human theft. Small species often prefer to roost under palm crowns.

Fig. 9.16. Adult Dog-faced Fruit Bat *Cynopterus sphinx* at rest; S. China.



Other mammal pests

Order ***Lagomorpha***

Common name Rabbits and Hares

In Australia a very spectacular pest is the introduced European Rabbit (*Oryctolagus cuniculus*) but it is found mostly in the arid grasslands which are used for livestock rearing - such populations would be devastating in agricultural locations. Their distribution has been controlled by miles of wire netting fences and also by the introduction of the pathogenic *Myxoma* virus. Rabbits are found in the coastal region of N. Africa.

In Africa and tropical Asia Hares (*Lepus* spp.) are found and sporadic damage may be done to growing crops, but these animals are solitary as opposed to the communal rabbits with their vast underground tunnel systems.

Occasional pests include Elephants (*Loxodonta africana* in Africa, and *Elephas maximus* in India and tropical Asia), *Hippopotamus* in Africa, and Buffalo in Africa and Water Buffalo in Asia. These are large heavy animals that live in herds or family groups and their attacks are infrequent but damage tends to be very seious when it does occur - severeal hectares of crops can be destroyed in a single night. They are all herbivores and eat a wide range of plant materials but their trampling is especially destructive.

Control in areas at risk has been to use barriers (electric fences, ditches, thorn fences/hedges, etc.) and scaring devices can be successful.

Order ***Carnivora***

Occasionally there are reports of farmers being attacked by maurauding lions (Africa) or tigers (India, S.E. Asia), but these are not technically crop pests and local game rangers have to be summoned to drive away or to shoot the predator. Civet Cats (Family Viverridae) are mostly predatory but the Palm Civet (*Paradoxurus hermaphroditus*) in S.E. Asia is omnivorous and eats a range of fruits, and is a pest of cocoa by destroying the pod husk to eat the seeds, but this is a protected species in most countries so control has to be judicious.

Class aves (Birds)

A number of different birds are recorded as damaging to growing crops (as well as taking grain and pulses from produce stores) ranging from the ducks and geese that paddle on the soil and flatten seedlings when thay graze, to the many that will feed on ripening fruits and ripening cereal grains. The gragarious species that live in large flocks can be especially destructive. There are several groups of birds that can be serious crop pets.

Order Passeriformes (Perching Birds)

These are birds that live in trees to a large extent and have feet adapted for gripping twigs; most are quite small in size. The two main groups of crop pests are the families Fringillidae (Finches) and Ploceidae (Sparrows and Weavers); they are granivorous, with a short stout beak capable of cracking open seeds and small cereal grains (ripe maize grains are too hard and large for them to eat). The pest species are gregarious and live in large flocks and can devastate ripening crops of small-grain cereals (rice, wheat, etc.).

Family Ploceidae (Sparrows and weavers)

A large family, worldwide in distribution with many different species; many are synanthropic and are also pests of cultivated plants.

Passer spp. etc.

Sparrows

Hosts Small-grain cereal crops when ripening (rice, wheat, sorghum, millets) are most at risk - maize is seldom attacked for the grains are too large and hard. These grains in storage are also taken.

Fig. 9.17. Passer montanus (Common Asian Sparrow)

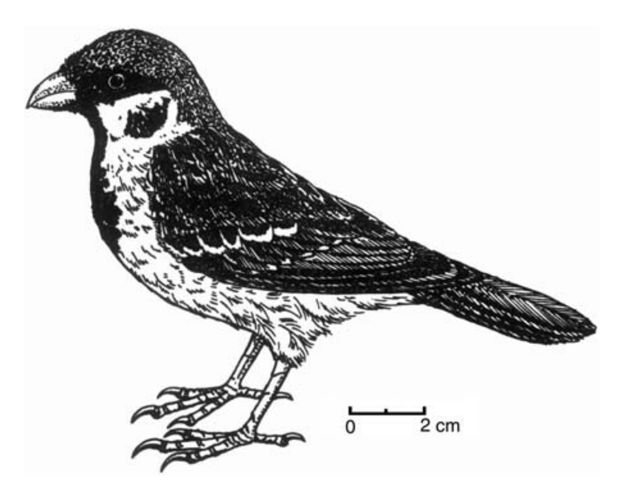


Fig. 9.18. Adult *Quelea quelea* ♂ & ♀

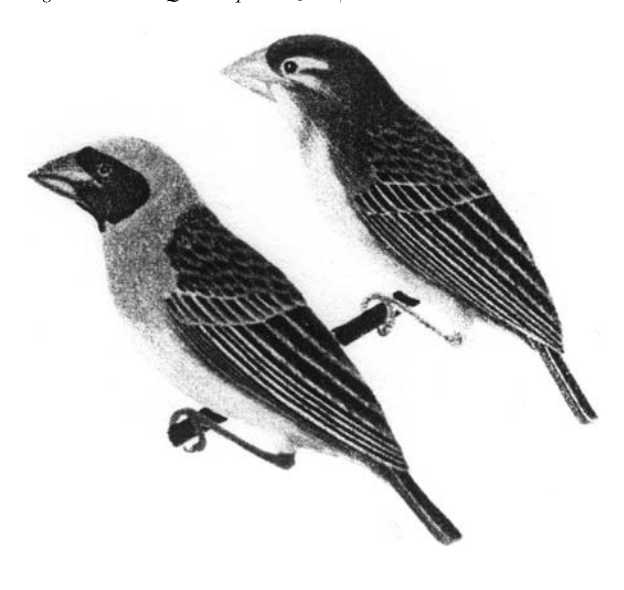


Fig. 9.19. Weaverbird damage to sorghum panicle; Ethiopia.



Pest status Only serious pests in scattered locations, but generally damage is very widespread, although often light. Recored as serious pests of paddy rice in S. America.

Life history They nest gregariously and each nest is made of plant materials, often strips of leaf lamina – it is domed with a short entrance tunnel. Nests are constructed in buildings or adjacent trees, but the truly gregarious species nest in small colonies dangling in trees or palms. Each brood is usually 4–6 and there are typically 2–3 broods per year. Typically the young birds gather at the end of the breeding season in large flocks and they search for food crops. In China several species are known locally as 'rice birds' and the juveniles are trapped in the rice fields in the autumn in their hundreds and thousands and are sold in local restaurants as a very popular food item.

Distribution The family contains 315 species, and 6 species of *Passer* are crop pests in Africa. *Padda oryzivora* (Java Sparrow) is now widespread throughout S.E. Asia including many of the larger islands, and is a major pest on rice crops. *Ploceus* spp. (some are known as Weavers) These are pests of small-grain cereals in parts of tropical Asia and Africa, and are very similar to *Quelea* in many respects.

Fig. 9.20. Weaver Bird nests; Ethiopia.

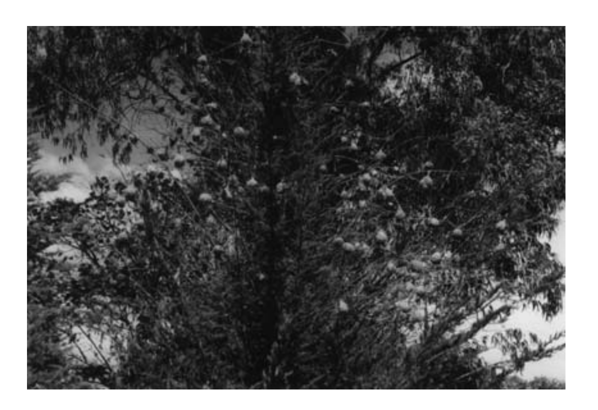


Fig. 9.21. Ripe papaya eaten by starlings; Ethiopia.



Fig. 9.22. Ripe avocado fruits eaten by starlings; Ethiopia.



Quelea spp.

Common Names Weavers; Queleas

Hosts Wild grass seeds are their preferred food, but they are very damaging to small-grain cereal crops (rice, wheat, barley, sorghum, millets).

Damage The feeding flocks often number several millions and they follow the ripening crops acress the continent. The cereal grains are eaten, and when a flock of several million birds descends on the rice fields the amount of grain eaten each day amounts to many tonnes, and the fields are soon stripped of grain. In a few weeks vast areas of cultivated cereals are devastated.

Pest Status Three species are particularly serious as crop pests throughout Africa South of the Sahara. The combination of high reproductive capacity, catholic diet, their mobility and migratory tendencies make them very serious pests.

Life History These species are gregarious and nest communally (Fig. 9.20) in trees and palms which are festooned with with the round woven nests. Some birds strip banana leaves for nesting material and the plants can be completely defoliated. Several broods of 4–5 young are produced each breeding season, and the young congrgate in enormous flocks for feeding and roosting purposes.

Distribution The three main species concerned are:-

Quelea quelea (Red-billed Quelea)	Most of Africa (not Congo) south of the Sahara.
Q. erythrops (Red-headed Quelea)	Found in Central Africa, not in Southern.
Q. cardinalis (Cardinal Quelea)	East Africa.

They migrate to different parts of the Continent and often breed locally. Control methods used include aerial spraying of avicides, use of flame-throwers and dynamite on both roosts and nest sites. In one year in S. Africa 100 million Quelea were killed but the devastation of farm crops continued. Scaring devices are widely used and can be successful, but at present no satisfactory method of control has been developed, but research continues.

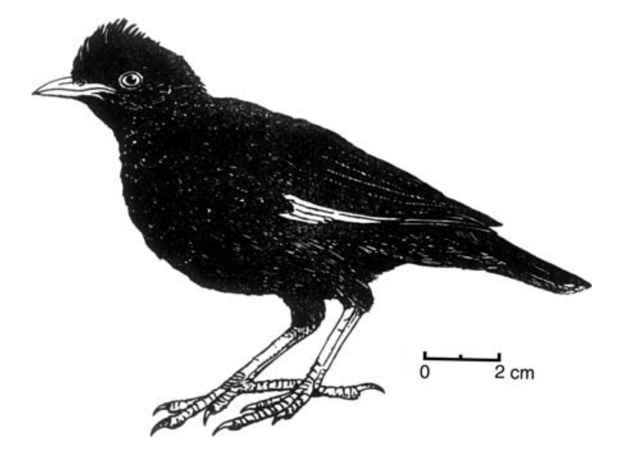
Starlings
Family Sturnidae

The two main groups concerned are the genus *Sternus* and *Acridotheres* (Mynahs). *Sternus* occurs worldwide as 16 species, mostly a Palaearctic group but now introduced into Australasia, New Zealand, S. Africa and N. America. They are recorded damaging rice and other grain crops, and a wide range of fruits, especially grapes, cherries, and germinating cereal grains may be eaten. Mynahs are found throughout tropical Asia. All starlings tend to be gregarious, often with metallic plumage (greens, blues, purple) – they are noisy and conspicuous, and many are good mimics. The beak is slender and not capable of breaking hard fruits or seeds, and most damage is recorded to grapes and other soft fruits, and small grains. In Africa about ten different genera are recorded, including the Oxpeckers which remove ectoparasites from the bodies of cattle and wild game. In some vinyards mechanical bird scarers are successful in driving the birds away. Strips of tin foil or white plastic dangling from strings are widely used.

Fig. 9.23. African Glossy Starling Ethiopia.



Fig. 9.24. Common Mynah *Acridotheres cristatellus* S. China.



Order columbiformes (Pigeons & Doves)

Family columbidae

Worldwide there are some 290 species, some quite large and plump, all are seed eaters. They often live in flocks for at least part of the year, and they can do extensive damage to both field crops and in grain stores. Their beaks are rather small and slender and cannot be used to crack open seeds – they rely on the muscular gizzard to crush the seeds. Normal feeding behavious is to quickly fill the crop with intact seeds and grains and then to fly off to a sheltered location to grind up the seeds in the gizzard for digestion; so in a short time they can consume a large quantity of grain. Most species nest singly and then form flocks later. Some field crops are also attacked and leafy vegetables can be stripped of foliage. Generally they are more important in temperate regions than in the tropics. The two main groups of pests are:-

Columba spp. (Pigeons) (Fig. 9.25)

Several species are worldwide and pests of some importance – feral populations of *Columba livia* are established in some locations, and this species is reared in large numbers in China as food (Wright, *et al*.; 1980).

Streptopelia spp. (Doves) (Fig. 9.26).

A more tropical group of smaller birds, and at least half a dozen species are recorded worldwide.

Fig. 9.25. Columba livia (Feral Pigeon).

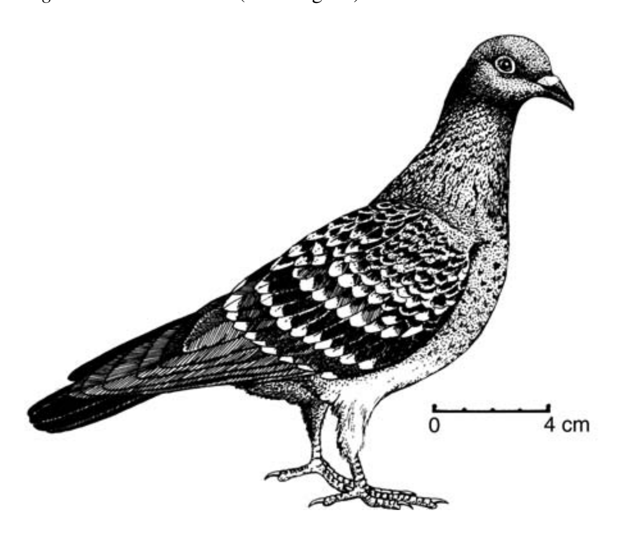



Fig. 9.26. Oriental Turtle Dove *Streptopelia orientalis.*

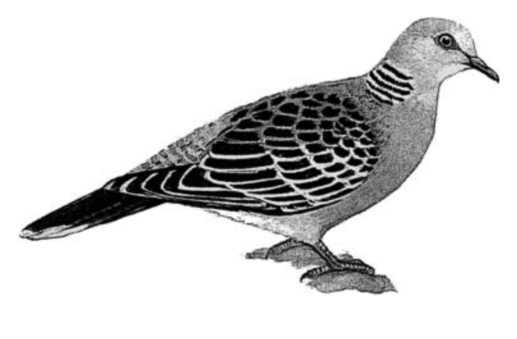


Fig. 9.27. Cabbage eaten by Pigeons.



Order psittaciformes (Parrots)

Family psittacidae (Parrots and parakeets)

A dozen or more species are found attacking fruit and grain crops throughout the warmer parts of the world. The main areas concerned are Australasia, S.E. Asia, India, Africa and S. America, where different species occur. In S.E. Asia they only became pests of importance after the etsblishment of oil palm plantations when food became available on a large scale. Ripe fruits are eaten but many are picked, pecked and dropped, and the damage somewhat resembles that done by rats. Feeding on oil palm occurs mostly for a couple of hours in the early morning and again at dusk when flocks emerge from the rain forest and descend on the plantations (Wood, 1968).

Control is seldome warranted and when attempted is not often successful.

Order accipitriformes (Birds of prey)

Family (Vultures: Accipitridae)

A most unusual occurrence is that in Brazil the Uruban Vulture has adapted to feeding on ripe oil palm fruits, and can be a pest locally.

Other vertebrata

Snakes are quite common in many plantation crops where they can pose a hazard for pickers and pruners; these include puff-adders (*Bitis* spp.) and mambas (*Dendroaspis* spp.) in Africa, and cobras (*Naja* spp.) in both Africa, India and S.E. Asia. Arboreal species such a the boomslang in Africa, and the tree-vipers and some pit-vipers (*Trimeresurus* spp.) can occasionally be a problem in tree plantations.

The tree frogs and lizards found on many bush and tree crop plants are beneficial species in that they feed on insects in the foliage, and do no damage to the plants and pose no threats to the workers.

Mollusa pests

Rice Snails
Gastropoda; Ampullariidae
A number of large, round-bodied pulmonates are to be found in paddy fields – they are amphibious and air-breathing so do not survive prolonged submergence.
Because of the large size and shape some are referred to as Apple Snails.
About a dozen species are found worldwide, and the main ones are as follows:
Ampullaria spp. - S. America
Globa spp. - S.E. Asia
Lanistes spp. - Egypt, C. and southern Africa
Pomacea spp. (= *Pila* spp.) - S. America
Adults can survive a long time (8 months) over the dry season by aestivating in the mud with the operculum closed tight. Destruction of rice seedlings can be extensive. Eggs are laid in clusters sometimes stuck onto plant stems.
In some regions the snails are regarded as good food and have been introduced deliberately.
Control is difficult to achieve; hand collection of the adults is effective, and duck predation of egg masses and young snails is successful. Many molluscicides have been tried with very mixed success - some are too phytotoxic to use.

Fig. 9.28. Lanistes sp. from Africa showing aperture closed by the operculum.

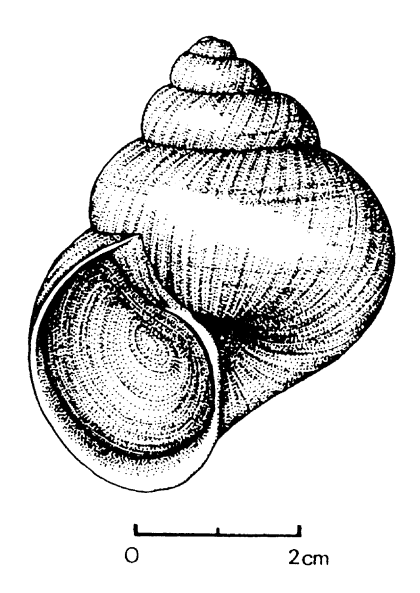


Fig. 9.29. Adult Apple Snail from the Sarawak highlands.



Achetina fullonica

Common name Giant African Snail

Family Achatinidae

Hosts A very wide range of plants are attacked, throughout the Old World Tropics.

Damage Foliage destruction by eating, and small plants may be destroyed; large holes are made in the plant leaves. Their nocturnal grazing goes up to a height of 2 metres. Paper notices may be eaten (Fig. 9.32). Telltale mucous trails and faecal strips are left behind.

Life history These are nocturnal feeders and spend the day hiding in leaf litter or under foliage. The toothed radula is the feeding organ and the scrapin action is very effective at grazing. Adults measure up to 10–12 cm and are striped brown in colour. These are non-operculate species and so when hibernating they close the mouth aperture with a dried mucus cover. Egg masses are laid in the leaf litter – eggs are large (1–2 mm) and globular.

Distrbution Native to tropical Africa this species has been introduced throughout tropical Asia, up to China, and the Pacific Islands where it is now well established.

Control Seldom really needed but hand collection, especially at night, can be effective since the snails are large in size.

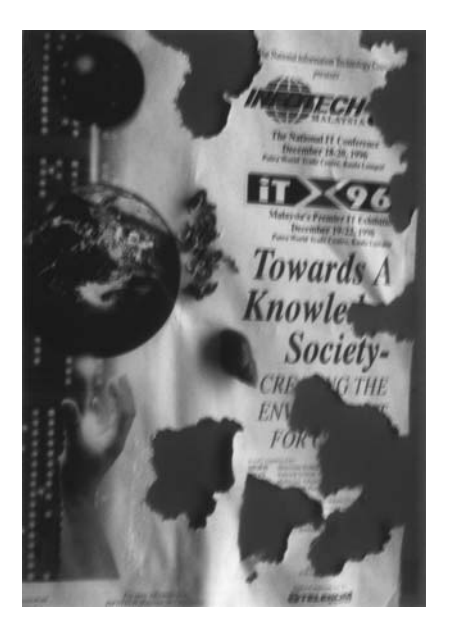
Fig. 9.30. Adult *Achetina fullonica.*



Fig. 9.31. Achetina adult feeding on plant leaves.



Fig. 9.32. Achetina damage to paper poster, UNIMAS.



Nematoda

(Phylum and Class Nematoda)
The plant parasitic nematodes, or eelworms as they are sometimes called, are a group of pests not easy to study and even more difficult to assess economically. In many agricultural situations soil nematodes are a constant local presence that have a depressive effect on crop yield; and it is quite probable that their effect is often as serious as the more obvious effects of insect pests. In addition to their own direct damage they often interact with pathogens with apparently synergistic effects, and some species are vectors of virus diseases. There is some interaction with insect pests as part of the total pest complex/load.

Body size varies from 0.2 mm to 10 mm, but averages about 1 mm in length and is thin in body form; the mouthparts include a spear (stylet) that is protrusible and used for piercing plant tissues. The plant pest species are categorised according to their lifestyle; as endoparasites, migratory endoparasites and ectoparasites. Many soil dwelling species are actually saprophytic, and not really pests. Some of the endoparasites have females that become globose and sessile.

Some of the more important nematodes that attack crop plants are described here.

Major nematode pests

Scientific name *Meloidogyne* spp.
Common name Root Knot Nematodes
Family Heterodidae

Hosts Half a dozen species are involved; most are individually polyphagous but the group is totally polyphagous. Several species have been recorded from as many as 700–800 different host plants; including a very wide range of crop plants in the warmer parts of the world.
Pest status Very serious pests of a wide range of crop plants; infestations result in a severe loss of yield.
Damage Above-ground symptoms are loss of plant vigour, wilting, loss of yield, increased susceptibility to pathogens, and sometimes death of the crop plant. Root symptoms are galls of varying size (depending upon the host species), and inside the galls are the pearly white swollen females, sometimes with a protuding gelatinous egg sac.
Life history Infective second stage larvae in the soil penetrate host plant roots and settle in the tissue inside. They feed and develop, some into vermiform males and most into thickened, saccate females. The larvae moult three times, but remain inside the cuticle of the second stage larvae. Overcrowding in the root tissues seems to induce male development; sometimes no males are produced and then reproduction is parthenogenetic. The females become very swollen and pyriform in shape, and the egg sac (in a gelatinous capsule) protudes through the wall of the root into the soil. Each female produces from 300–1,000 eggs or even more. The eggs hatch and the young (first stage) larvae leave the egg sac and are free-living as they seek new host plants to infect. Mature males measure 1–2 mm in body length, and the pyriform females are the same order of size but subglobose.

The life cycle is of variable duration according to temperature; at 20°C it takes about 57 days, and at 27°C some 23–30 days.
Distribution The genus *Meloidogyne* is worldwide in the warmer regions, represented by 16 species; some species are more tropical than others. Some extend up to southern USA and southern Europe, and may be found in greenhouses in northern Europe and Canada. One or two tropical species are very host specific and are confined to tea or coffee.
Control Several aspects of control have to be considered:
Cultural methods: Crop rotation with non-susceptible crops can be very effective; also the use of resistant varieties of crops. Hot water treatment will kill nematodes in seeds and on planting material, but is not effective against Root-knot Nematodes.
Chemical control: The most widespread nematicides in general use are the soil fumigants such as D-D, ethylene-dibromide, and methyl-bromide; usually applied through an injector mechanism into the soil at preselected depths. There is an increasing use of non-volatile nematicides such as oxamyl, and the granular formulations of aldicarb and other carbamates, which can be applied by the bow-wave technique in the seed drill.

Nursery seed beds can be quite easily fumigated, but field scale operations are more difficult and generally very costly, and on this scale granular formulations are more suitable.

Crop sampling is generally recommended to assess infestation levels before soil treatment is undertaken, but damaging population levels vary from crop to crop and according to the nematode species, so local advice should be sought as to appropriate survey methods.

Control of nematodes

Control methods

Cultural control: Control measures are primarily preventative. Crop rotation is particularly important for the major soil-borne nematode parasites of annual crops. Many endoparasitic nematodes have adult reproductive stages which are obligately parasitic, and in the absence of a suitable host they cannot survive and reproduce. The most important group (root-knot nematodes) have a wide host range so that the crops chosen in the rotation are important and this varies with the species concerned. As a general rule cereals, grasses or other monocots are not hosts of the root-knot species affecting vegetables, cotton, tobacco, etc.

On perennial crops, control is more difficult but because dispersal of nematodes in soil is very limited, it is essential that planting material is free of nematodes. This applies particularly to nematode parasites of coffee, banana, citrus, etc. Once nematodes become established on these crops and populations reach damaging levels, chemical control may be needed.

Other control methods include the use of resistant cultivars when these are available, e.g. for tomatoes and the use of biological control methods which are currently in the developmental stage.

Chemical control: This usually consists of either injecting a volatile chemical (usually a chlorinated hydrocarbon such as ethylene dibromide or dibromochloropropane) into the soil, or applying granular formulations to the soil. Several systemic chemicals such as carbofuran, oxamyl or aldicarb (which is extremely toxic and should only be used under close supervision and with protective clothing), are now commonly used. Soil sterilisation techniques using heat or fumigants will eradicate parasitic nematodes from nursery beds before planting.

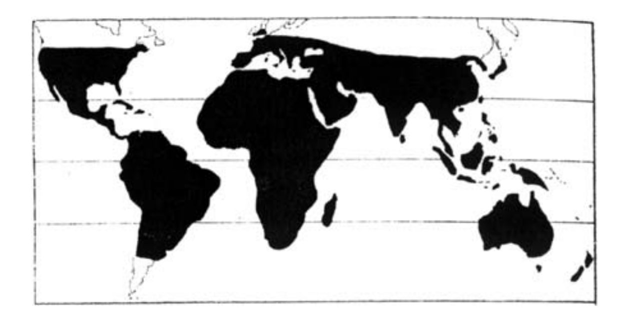


Fig. 9.33. Root Knot nematode *Meloidogyne* sp.

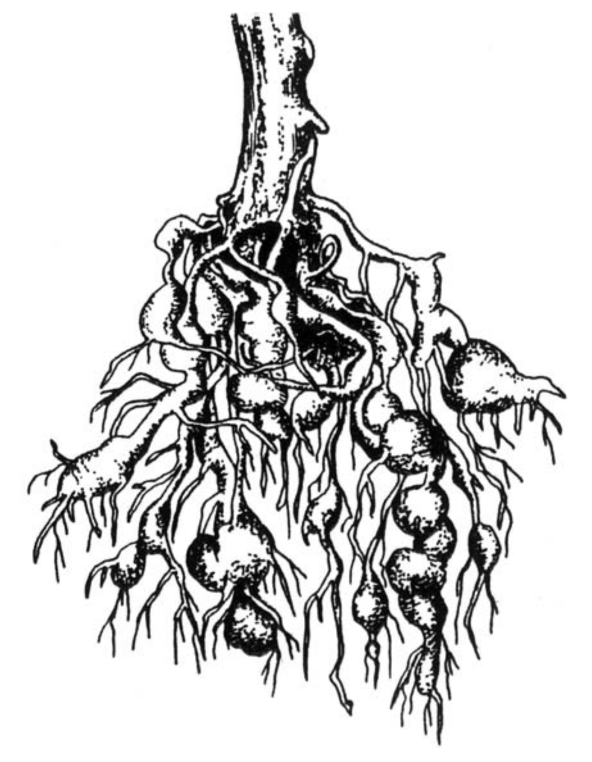


Fig. 9.34. Root-Knot Nematode (*Meloidogyne* sp.) on roots of Red Beet, Ethiopia.



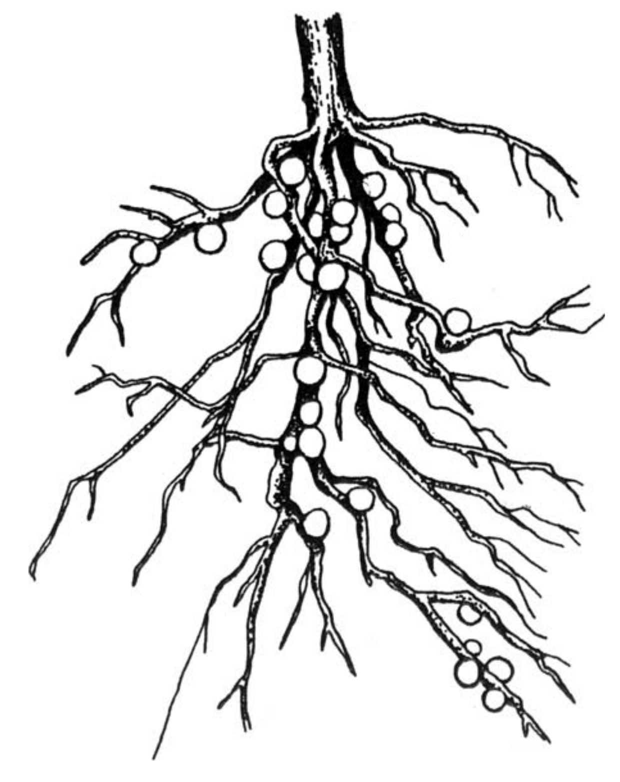
Other nematode pests

Globodera/Heterodera spp. (Globose females encyst on roots; several species on different crop groups; mostly temperate but at high altitudes in the tropics; some tropical)	Cyst Nematodes (Rice Cyst Nematode Sugarcane Cyst Nematode)	Heterodidae	Cosmopolitan
Pratylenchus spp. (Obligate plant parasites; polyphagous; many species tropical; make lesions in root tissues when they invade the host; often interact with pathogenic fungi)	Root Lesion Nematodes	Hoplolamidae	Cosmopolitan
Tylenchulus spp.	Citus Root Nematode	Hoplolamidae	Pantropical
Ditylenchus spp. (Most temperate, some tropical; polyphagous in both mono- and dicotyledons; regarded as ectoparasites)	Stem Nematodes	Tylenchidae	Cosmopolitan
Xiphinema spp. (Migratory root ectoparasites; many host plants; virus vectors)	Dagger Nematodes	Dorylaimidae	Cosmopolitan
Longidorus spp. (Temperate and tropical species; both direct damage and virus vectors; many hosts)	Needle Nematodes	Dorylaimidae	Cosmpolitan
Trichodorus spp. (Subtropical and temperate; most damage mechanical, but also virus vectors)	Stubby Root Nematodes	Trichodoridae	Cosmopolitan
Aphelenchoides besseyi	Rice Leaf Nematode		Pantropical
Hirschmanniella spp.	Rice Root Nematode, etc.		
Tylenchorhynchus martini	Rice Stunt Nematode		

Fig. 9.35. Citrus Root Nematoda (*Tylenchulus* sp.) Roots stunted and bushy.



Fig. 9.36. Root Cyst Nematode (*Heterodera* sp.) Roots with small round cysts.



Insecta

The orders and families of insect pests are arranged according to the 9th edition of Imms *A General Textbook of Entomology* as revised by Richards & Davies (1960), and within the family the species are arranged alphabetically. The only exceptions are the families Scarabaeidae and Chrysomelidae of the Coleoptera, which are very large groups with well-defined sub-families with important biological differences between the different subfamilies; with these two families the important pest species are separated into their respective subfamilies.

It must be stressed that all the chemical control recommendations in this chapter are tentative and intended more as a guide than as definite recommendations. This is in part because invariably chemical control recommendations are out of date by the time they are published, and also there is no generally agreed international list of recommendations for pesticide use: a chemical approved in one country may be banned in another as most countries have different approval criteria. This is now more apparent than ever, as some countries have imposed blanket bans on the use of the organochlorine compounds whereas in others DDT, BHC, dieldrin and the like are still recommended. In this book it is attempted to point out which chemicals are, or have been, effective in killing particular pests, whether or not they are available, or approved, by any particular country. Local advice *must* be sought for details of recommended treatments for local pests, as these will take into account chemical availability, approval, local climatic and soil conditions, and any local resistance problems.

Order **Orthoptera**
Medium-sized or large insects, with the forewings thickened and modified as tegmina, although some have the wings reduced or absent; the hind legs are usually enlarged for jumping; biting mouthparts; metamorphosis is only slight; they often have specialized auditory and stridulatory organs; the female usually has a well-developed ovipositor.

Family **Gryllidae**
(Crickets) Many apterous species; some are arboreal (bush crickets); the antennae are very long; they are omnivorous and live in warm places; many burrow in the soil; the female has a long straight ovipositor and long unsegmented cerci; eggs are usually laid in the soil, and some species construct underground chambers for this purpose, other species lay their eggs in the pith of twigs. About 900 species have been described.

Family **Gryllotalpidae**
(Mole crickets) These are characterized by various adaptations to a subterranean habit; the forelegs are greatly expanded and armed with strong teeth for digging; eyes and antennae are reduced; ovipositor is vestigial; winged species are strong fliers, but apterous and brachypterous species occur; a subterranean nest is constructed for breeding purposes. There are about 50 species, some of which are pests of agricultural importance.

Family **Acrididae**
(Short-horned grasshoppers and locusts) The antennae are short, much less than the length of the body; the locusts are essentially gregarious species capable of swarming both as nymphs and adults, whereas the grasshoppers are solitary; eggs are laid in pods in the ground; certain species in S.E. Asia are aquatic in habit. Many species are crop pests; when swarming, the locusts are devastating. About 5000 species are known.

Family **Pyrgomorphidae**

(Stink Grasshoppers) A group of great antiquity with various primitive features. Most have a conical head, seen in profile, with a fine groove at the tip of the vertex. The other family characteristics refer mainly to the male genitalia. Many species are minor or sporadic crop pests, in Africa and S.E. Asia. Many will feed on poisonous plants and are themselves toxic and can secrete a noxious fluid. People have died after eating these insects.

Acheta spp.

Common name Field Crickets
Family Gryllidae
Hosts General pests that live in the soil and at night attack many different herbaceous crops. Will damage tea and coffee seedlings by eating the bark.
Damage Young plants generally have parts of the foliage eaten, and young woody plants may have the bark gnawed away in patches.
Pest status A sporadically serious pest of many different crops, particularly at the seedling stage, only occasionally causing economic damage.
Life history The elongate, banana-shaped, yellow eggs are laid in batches of up to 30 in the ground, by the female using her long ovipositor. Each female cricket lays up to about 2000 eggs. At 26°C the eggs hatch in 10–12 days, and development of the nymphs takes 40–60 days more. Adults generally live for 2–3 months. These insects are omnivorous, and laboratory studies have shown that normal development requires a diet including other insects.

Total development takes some 50–80 days, according to climate and diet, and in the tropics there are usually four generations per year.

The adult is a dark brown or black cricket, with a body length of 2–3 cm; the cerci are long, and the female has a long ovipositor, some 15–18 mm.
Distribution The two main species concerned are *A. bimaculata* (De Geer) (Two-spotted Cricket) found throughout Africa, southern Europe, and parts of Asia, and *A. testaceus* Wlk. found throughout S. China and S.E. Asia.
Control Damage is usually not sufficiently serious to warrant control measures, but if required a bran bait mixed with chlorpyrifos, or various pyrethooids should be effective.

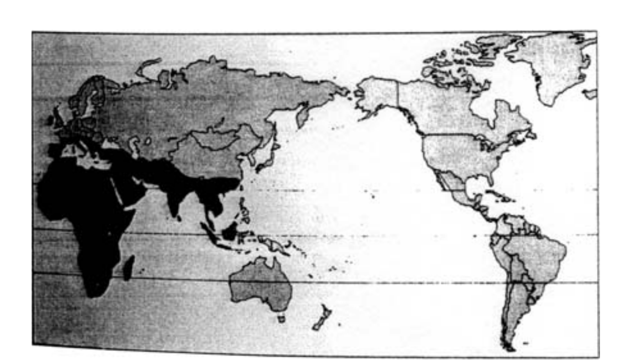
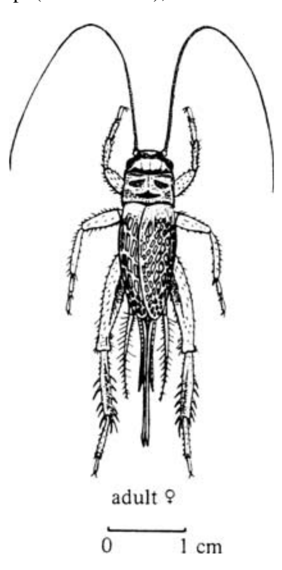


Fig. 9.37. Acheta sp. (Field Cricket); S. China.



Branchytrupes membranaceus (Drury)

Common name Tobacco Cricket
Family Gryllidae
Hosts Many crops are attacked, including tobacco, tomato, tea, and cotton; seedlings are particularly vulnerable.
Damage Seedlings are cut off and dragged into underground burrows, or left on the surface wilting for a few days before being taken into the burrow.
Pest status A local sporadic pest of many crops, particularly at the seedling stage, and on light sandy soils where the adult crickets can easily burrow.
Life history The eggs are elongate-oval, 3–4 mm long when first laid, and white, later becoming brown and expanding to 5–6 mm. They hatch after about one month.

The full-grown nymph is a fat, brown insect 4–5 cm long; there are four nymphal instars, the total nymphal period taking about eight months.

The adult is a large, fat, brown insect with a heavy square head, long thin antennae, and powerful hindlegs. The body, excluding appendages, is about 5 cm long. The adult female may live for three or four months and will lay over 300 eggs.

Newly hatched nymphs leave the burrow of the mother cricket and construct one of their own. It is gradually enlarged during the nymphal period, finally reaching a depth of 60–80 cm in sandy soil. The adult stage is reached at the start of the rainy season and eggs are laid in batches in the burrow three to four months later. Both nymphs and adults collect seedlings, leaves, and other soft vegetation, both dead and alive, and drag them into their burrow where they are stored and finally eaten. Fresh sappy material is often left on the surface for a day or two to wilt before being taken below ground.
Distribution Widespread in tropical and southern Africa, down to the Transvaal.
Control See *B. portentosus*.

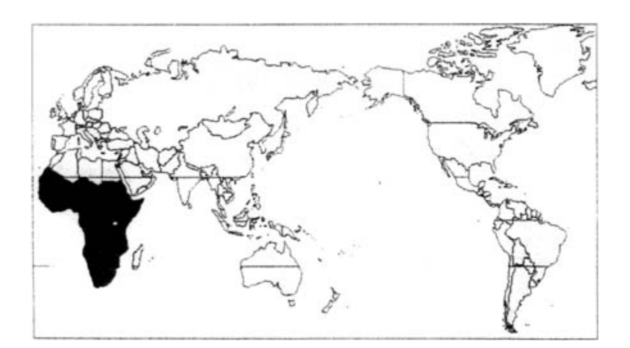
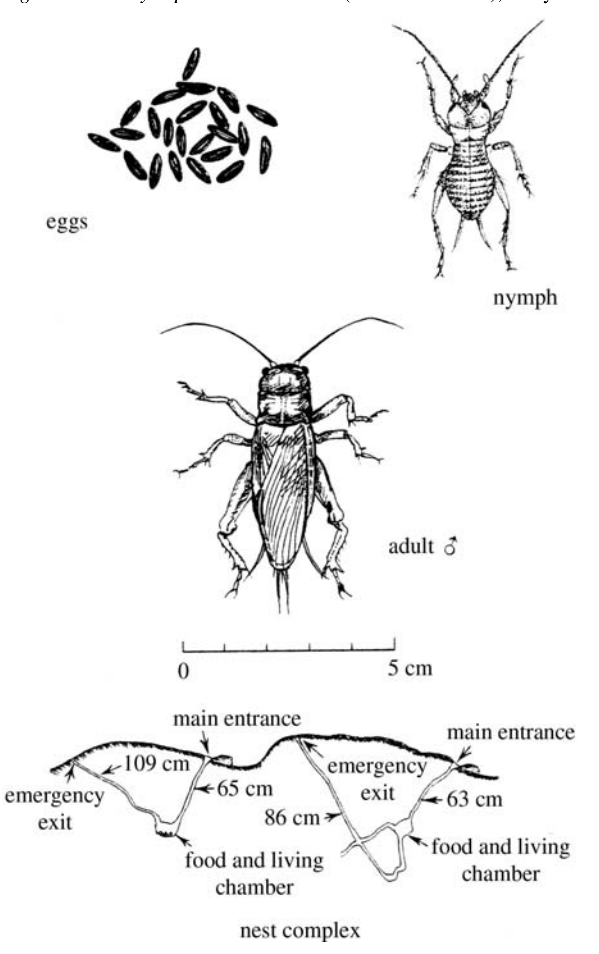


Fig. 9.38. Brachytrupes membranaceus (Tobacco Cricket); Kenya.



Brachytrupes portentosus Licht.

Common name Large Brown Cricket
Family Gryllidae
Hosts Many field crops are attacked; seedlings are particularly vulnerable; but little host specificity is shown.
Damage Typically seedlings are cut through and dragged into the underground nest where they are eaten.
Pest status A sporadic pest, of polyphagous habits, feeding on many different crop plants; particularly damaging to seedlings, and more numerous on light sandy soils where burrows are easy to excavate.
Life history The life history details are much the same as for *B. membranaceus* as the two species are very closely related.
Distribution This genus is represented in tropical Africa by the species *B. membranaceus* and in tropical Asia by the allopatric *B. portentosus* which is also found in Papua New Guinea. Indonesia.
Control When control is required, a bran bait is generally effective when mixed with fenitrothion Maize flour can be used but is generally not so effective as wheat bran. The moist crumbly mixture should be broadcast between the crop rows in the evening (for the pest is nocturnal) on weed-free soil.

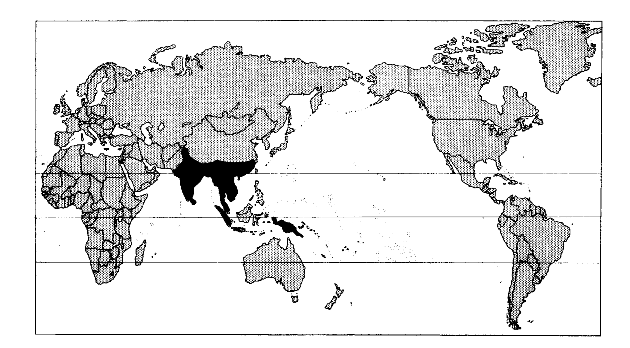
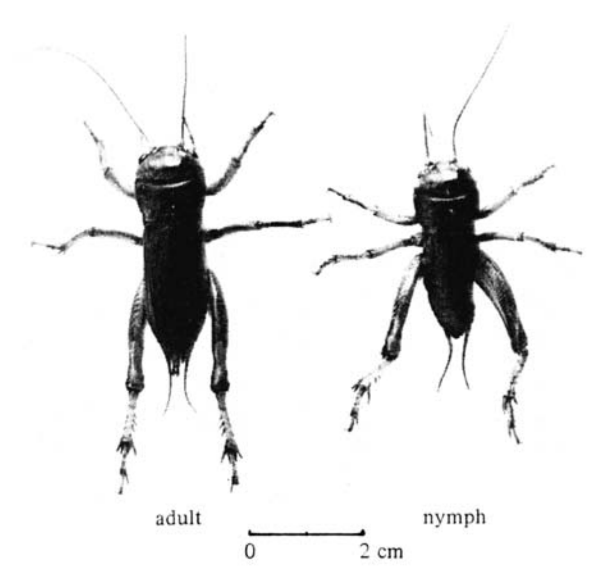


Fig. 9.39. Brachytrupes portentosus (Large Brown Cricket), S. China





Entrance to nest tunnel

Gryllotalpa. spp.
G. africana Pal.
G. orientalis Burm.

Common name Mole Crickets
Family Gryllotalpidae
Hosts A general pest attacking many herbaceous crops, especially at the seedling stage. Some shrubs (e.g. tea) are also attacked in propagating beds.
Damage Heaps of soil mark the entrances to extensive burrows in the soil. Plants wilt owing to destruction of roots. Small seedlings may disappear completely during the night. Buds are eaten from sugarcane setts; potato tubers are tunnelled.
Pest status A sporadically serious pest, especially at lower altitudes, and particularly in moist soil.
Life history The eggs are oval, brown, and 1.5 mm long, and laid in chambers at the end of burrows 10–15 cm below the soil surface. The female mole cricket may construct three or more of these chambers and lay a total of about 100 eggs distributed between them. Eggs hatch after two or three weeks.

The first stage nymphs remain in the egg chamber and are fed by the mother. Subsequent instars live in burrows during the day and forage for food on the soil surface at night. There are 9–11 instars and the total nymphal period lasts for ten months.

The adult cricket is about 2.5 cm long, brown, and covered with short setae giving it a velvety appearance. The wings are folded and do not cover the full length of the abdomen. The forelegs are broad and curved and clearly adapted for digging. Like the nymphs the adults live in burrows or shelter under pieces of trash in the daytime and feed at night. Mating takes place about ten days after the last moult and egg-laying begins one or two weeks later. Eggs are laid in the rainy seasons, and as the total life-cycle takes about a year, there are probably two overlapping generations present in the field. Adults live for at least two or three months.
Distribution. Cosmopolitan in the warm regions of the Old World; comprising Africa, Mauritius, Egypt, Asia, the Far East, Australasia, and the Pacific islands (CIE map no. A293).
Control. As with *Brachytrupes portentosus*.

Some 70 species of Mole Crickets are known worldwide, but only a small number are regarded as pests. In the New World some *Gryllotalpa* are found but *Scapteriscus* is the local genus and several pest species are known. (See Frank & Parkman, 1999)

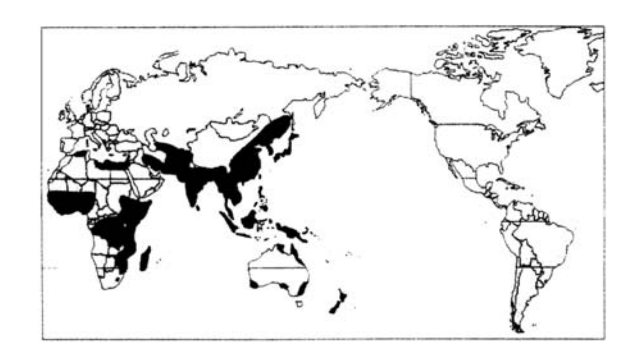
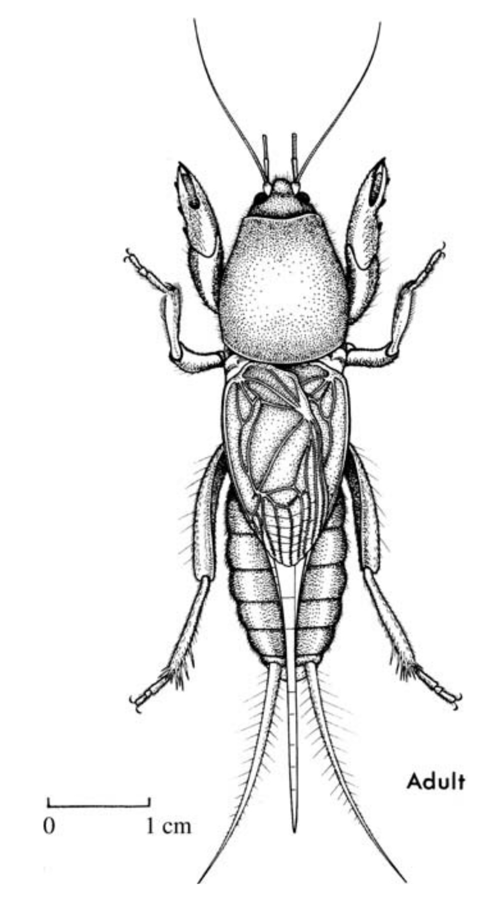
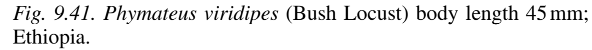


Fig. 9.40. Adult Mole Cricket (*Gryllotalpa* sp.)



Phymateus viridipes (Stal)

Common Name Green Bush Locust
Family Pyrgomorphidae
Hosts Recorded equally from wild plants (herbs, shrubs, trees, grasses) and cultivated ones - some 40 different crops are damaged.
Damage Eating of foliage is the main type of damage but bark and fruits may be destroyed, especially on citrus species. When insect numbers are high damage can be very extensive.
Pest Status A species regularly recorded as of substantial importance in tropical Africa - the other species (9 in total) generally of minor or irregular importance.
Life History A large grasshopper, 6–7 cm long, of distinctive reddish/yellow colouration and pronotum with red protuberances (bosses). Eggs are laid in sandy soil and require 4–10 months for development. Sometimes it appears that the life cycle may require two years. The hoppers pass through seven stages which takes some four months and are markedly gregarious and resemble true locusts. The food plants include various poisonous species and the insects can exude a malodorous fluid from an abdominal gland, which earns them the name of Stink Grasshoppers.
Distribution E., Central and southern Africa; nine other species are found throughout tropical Africa and Madagascar.
Control Generally difficult to kill with contact insecticides, but in the past dieldrin and carbaryl were successful as either high or low-volume sprays.


Fig. 9.41. Phymateus viridipes (Bush Locust) body length 45 mm; Ethiopia.



Zonocerus spp.
elegans (Thun.)
variegatus L.

Common name Elegant Grasshoppers
Family Pyrgomorphidae
Hosts (main). Many crops in the seedling stage, especially cassava, and finger millet.

(alternative). A wide range of dicotyledenous crops and weeds, e.g. cocoa, cashew citrus castor, coffee, cotton, and sweet potato. Grasses and cereals are not usually attacked.

Damage The leaves of seedlings are eaten, leaving ragged edges. Nymphs and adults which are both gregarious and sluggish may be found on the leaves of the crop.

Pest status A sporadically severe pest of many crops, especially in the seedling stage, in parts of Africa.

Life history Eggs are sausage-shaped, 6 mm long and 1.5 mm wide. They are laid in the soil in masses of froth which harden to form sponge-like packets about 2.5 cm long. Laying takes place from March to May and hatching in October and November. Each female can lay about 300 eggs.

The nymphs are typical short-horned grass-hoppers about 3 cm long when full grown. They are black, the appendages ringed with yellow or white. The total nymphal period lasts for about four months; there are five instars.

The adults are handsome grasshoppers about 3.5 cm long, generally dark greenish but with much of the body boldy patterned in black, yellow and orange. Short-winged specimens which cannot fly are very common. The adult life span is about 3–4 months. They have a characteristic unpleasant smell, and are sometimes termed 'stink grasshoppers'.

There is only one generation of these grasshoppers per year.

Distribution *Z. elegans* is recorded from S. Africa, Angola, Zaïre, Malawi, Mozambique, and Zimbabwe. *Z. variegatus* extends right through from W. to E. Africa.

Control Dieldrin and carbaryl have been very successfully used in high- and low-volume applications.

Alternatively a bait may be used instead of a spray and then aldrin or BHC dust were used mixed in with wheat bran. The mixture should be moistened with water to make a crumbly mash which is broadcast between the crop rows in the evening, preferably on weed-free soil, carbaryl can also be used.

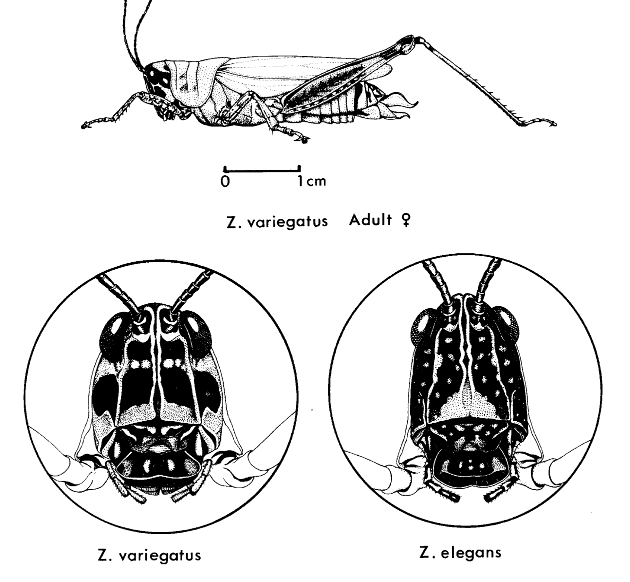


Fig. 9.42. Elegant Grasshoppers (*Zonocerus* spp.)

Grasshoppers and locusts

Family Acrididae
Hosts (main). Grasses and cereals (wheat, barley, rice).
(alternative). Alfalfa, clovers, cotton, buckwheat, tobacco, flax, tomato, potato, and other crops are occasionally attacked.
Damage Grazing by both adults and nymphs causes loss of leaf lamina; severe attacks by large populations can result in complete defoliation.
Pest status In places where the natural climatic climax vegetation of grassland has been ploughed for agriculture, or where the grassland persists for pasture, grasshoppers (Acrididae) are often the dominant insect fauna, and may be serious pests, especially where the grasslands (prairies, steppes, etc.) are used for cereal growing. Only occasionally are populations sufficiently large for the species to be a serious pest, but the various species are widespread and common.
Life history Eggs are laid in pods in the soil. In temperate regions oviposition occurs in the late summer and autumn and the eggs overwinter, hatching in the spring. Egg-pods may contain from 15–80 eggs, each female laying several pods over a period of 2–3 months.

There are usually six or seven nymphal instars. During the later stages food may become scarce (oviposition sites are often concentrated in small locations) and nymphal migrations are common. Nymphal development usually takes 40–60 days.

The adults are mostly large insects, up to 50 mm in length, and sometimes 70 mm, either brown or green in basic coloration. Several species are regularly migratory in habits and may be serious pests. The Acrididae are basically grassland insects and feed predominantly on Gramineae, but some are quite polyphagous and will feed on many dicotyledonous plants. The species that are short-winged and flightless are often good climbers and may defoliate trees up to 4 m in height. The Pyrgomorphidae are mostly polyphagous on shrubs and small trees (Citrus, cashew, cotton, etc.).

The true locusts are species that are dimorphic with solitary and gregarious phases that differ in coloration and in behaviour – only the gregarious phase being migratory. Not all common names are accurate in this respect.

There is usually only one generation per year; overwintering occurs in the egg stage in temperate regions.



Fig. 9.43. Pair of *Zonocerus elegans* mating on cashew foliage in Tanzania, these are brachypterous forms.



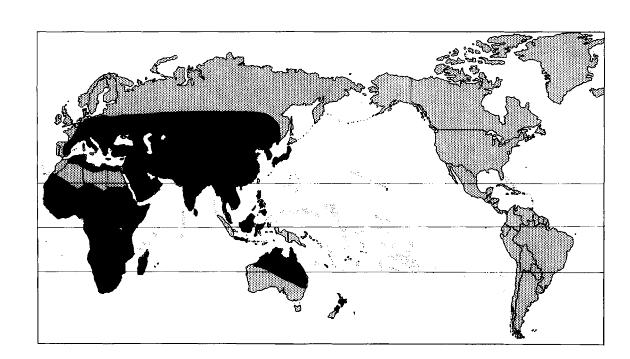
Grasshopper and locust pests

The main tropical species of classical notoriety are as follows:

***Locusta migratoria* L.** – (Migratory Locust) a pest of cereals and pastures and some other crops; occurs as three distinct subspecies, the African. Asiatic and the Oriental Migratory Locusts. The Asiatic subspecies extends as far as Australia.

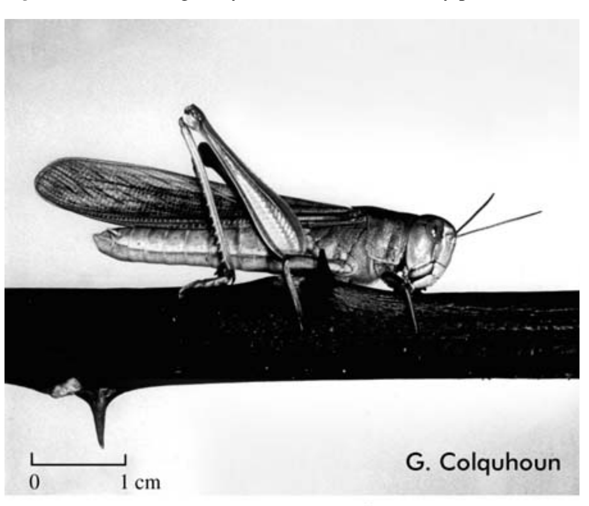
***Nomadacris septemfasciata* (Serv.)** – (Red Locust) only Africa: on Gramineae and other plants.

***Schistocerca gregaria* (Forsk.)** – (Desert Locust) occurs throughout Africa to India: polyphagous but with a preference for Gramineae; devastatingly serious pest in the past.



Two other more tropical genera of importance are *Oxya*, the Small Rice Grasshoppers of Asia (CIE map no. A.295), and *Zonocerus*, the Elegant Grasshoppers of Africa, which are quite serious, polyphagous pests (CIE map no. A.322).

Fig. 9.44 African Migratory Locust, adult ♂, solitary phase.



Other pest species include:

Austracris guttulosa (Wlk.) – (Spur-throated Locust) Australia; polyphagous.
Austroicetes cruciata (Saussure) – (Small Plague Grasshopper) Australia; grasses and wheat attacked.
Camnula pellucida (Scudder) – (Clearwing Grasshopper) Canada and USA; cereals and some other crops attacked.
Chortoicetes terminifera (Wlk.) – (Australian Plague Locust) feeds on pastures, field crops and vegetables (polyphagous); recent plague in 1984 througout NSW and into Victoria and Queensland.
Dociostaurus maroccanus (Thnb.) – (Mediterranean Locust) Mediterranean Region and Middle East; on cotton and cereals (CIE map no. A.321).
Gastrimargus marmoratus – (Marbled Grasshopper) China, Japan and S.E. Asia.
Gastrimargus africanus S. – Africa, India.
Gastrimargus musicus (F.) – (Yellow-winged Locust) Australia; cereals and sugarcane attacked.
Melanoplus spp. – about 10 species occur in Canada and USA; several are important pests; some migratory; polyphagous on cereals, vegetables and field crops.
Phaulacridium vittatum (Sjostedt) – (Wingless Grasshopper) Australia; polyphagous.
Schistocerca americana (Drury) – (American Grasshopper) USA; Gramineae.
Schistocerca spp. – (Locusts) Canada and USA; alfalfa, clovers, Gramineae.

Control of grasshoppers (Acrididae)

Many species of predators and parasites feed on Acrididae and are of importance in the natural control of populations. Important predators include man, many birds, lizards, toads, frogs, some small mammals, some wasps, meloid beetles. Parasites include various Diptera and Hymenoptera mostly. The Meloidae egg predators/parasites are particularly important in controlling many pest populations.

Chemical control is used in several different aspects:

(1) Poison baits – bran mixed with aldrin, HCH, dieldrin or carbaryl powders.
(2) Swarming locusts sprayed aerially with DNOC, dieldrin, HCH, parathion.
(3) Ground spraying or dusting with dieldrin, HCH, parathion, malathion or carbaryl.
(4) Grasshoppers on oil palm in Papua New Guinea are controlled by trunk-injected monocrotophos.

When large swarms, or scattered large populations, are to be controlled then clearly aerial spraying or the use of large power-driven sprayers or dusters is necessary.

The most important locust species are dealt with in the Anti-Locust Research Centre (1966) *Locust handbook*, but a more exhaustive treatment is given in the COPR (1982) book *The locust and grasshopper agricultural manual* where several hundred species are considered.

Locusta migratoria sspp.
L. m. migratoria (L.) Asian Migratory Locust
L. m. migratorioides (R. & F.) African Migratory Locust
L. m. manilensis Oriental Migratory Locust
L. m. sspp. (7_+)

Family Acrididae

Hosts Preferred hosts are Gramineae, both wild and cultivated, but a very wide range of other plants are recorded.

Damage The scattered solitary forms cause negligible damage, but the swarms cause complete defoliation of crops thus extensive damage.

Pest Status These are sporadically serious pests throughout Africa and the warmer parts of Asia. Swarms of both hoppers and adults are very damaging. Each subspecies has its own outbreak areas and the much larger invasion areas.

Life History Eggs are laid in pods in sandy soil and each female lays four or five batches. Eggs hatch in 10–25 days, or more in cooler climates. Six nymphal instars are usual taking 26–61 days. Adults live for up to 100 days. Most subspecies are multivoltine with 4–5 generations, but further north there may be only a single generation per year. Adults are large insects, 35–40 mm for males, and 40–50 for females. In the solitary phase the hoppers are green and the adults pale yellowish; in the gregarious phase the hoppers become orange and black, and the adults spotted and banded. The subspecies are difficult to identify morphologically.

Distribution The group occurs from western Europe to E. China and Japan, and south to Africa, India, S.E. Asia and Australasia, but most are actually allopatric (see COPR, 1982; p. 455).

Control In the solitary phase this is seldom needed. The plague outbreaks are difficult to forecast but rainfall studies are being used with some success. For further details see page 151.

Nomadacris septemfasciata (Serv.)

Common name Red Locust
Family Acrididae
Hosts Preference is shown for grasses and graminaceous crops, but a great variety of crops may be attacked.
Damage The leaves are eaten from the margin inwards; in a heavy attack the entire lamina is eaten away. Swarm damage can be devastating and result in complete crop defoliation.
Pest status A sporadically serious pest in tropical Africa south of the Sahara. The outbreak areas are in the Rukwa rift valley of Tanzania, the Mweru marshes of Zambia, and the Chilwa plains in Malawi. The last plague began in 1930 and finally ended in 1944.
Life history Eggs are laid in pods containing about 100 each, three or four pods being laid per female. The eggs are laid in the wet season (November to April), and they hatch in about 30 days without going into diapause.

There are seven stages of hoppers in the solitary phase and six in the gregarious. The hoppers are red, black and yellow, and take from 2–3 months to develop.

The adults are the largest dealt with here, the male being 50–60 mm long and the female 60–70 mm. The body is yellow-brown; prothorax with broad, yellow and red longitudinal bands. The costal and inner margin of the forewing is banded yellow, the remainder being translucent brown. The tibia of the hindlegs are reddish, and the base of the hindwing is characteristically red. There is a stout spine between the bases of the forelegs.

The adults live for about nine months, waiting until the wet season before egg laying.

There is only one generation of Red Locusts per year.
Distribution Central and southern Africa, from Angola to Somalia and E. Africa and southwards to S. Africa. The breeding areas are the Lake Rukwa region of Tanzania, the Mweru marshes of Zambia, and the Chilwa plains of Malawi.
Control The hoppers can be killed with the use of a bait made of wheat bran with BHC dust or aldrin w. p. added. Spraying with carbaryl, dieldrin or aldrin, is effective against hoppers, and dieldrin, BHC or DNOC against flying swarms.

Control generally is as for Desert Locust.

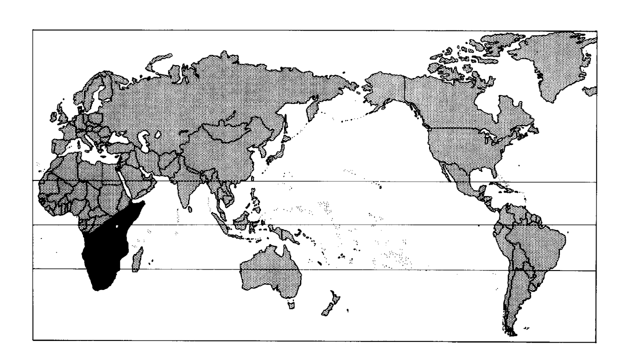
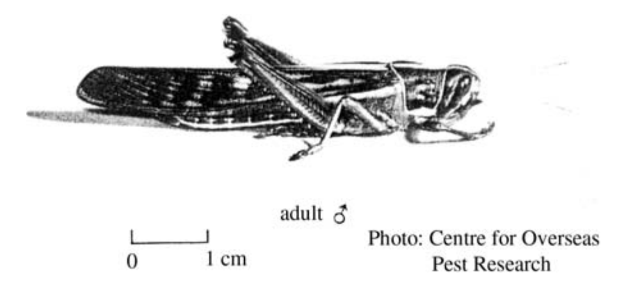


Fig. 9.45. Nomadacris septemfasciata (Red Locust); Kenya.

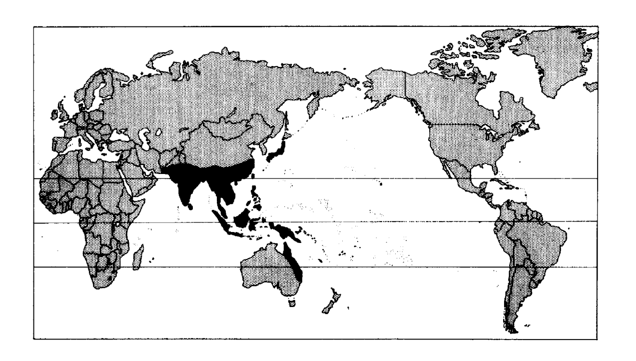


Oxya spp.
chinensis Thnb.
japonica (Thnb.)

Common name Small Rice Grasshoppers
Family Acrididae
Hosts (main). Rice
(alternative). Many species of grasses (Gramineae), occasionally various herbaceous plants.
Damage Adults and nymphs eat the foliage of the rice plants; on older plants the adults may eat the base of the rice panicle, causing it to wither and die.
Pest status Of sporadic importance in different parts of their wide distribution range, only occasionally requiring control measures.
Life history As with other Acrididae the eggs are laid in a pod just below the soil surface, but since these grasshoppers typically inhabit wet areas the eggs may be laid in a mass of froth (which hardens to form the protective 'pod') a few centimetres above the water level on the rice or grass foliage.

In more northern regions there is only a single generation per year, and they overwinter in the egg stage. In the warmer regions breeding appears to be more or less continuous.

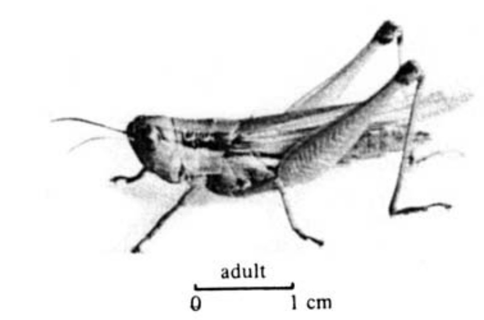
Young males generally pass through six instars, whereas many females apparently have seven instars. They are alleged to swim quite well and can gain access to the rice plants in flooded fields in this way.

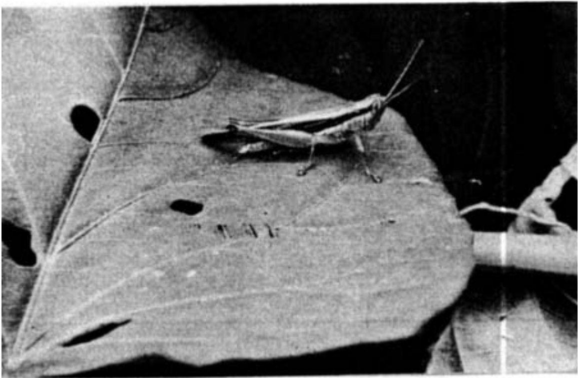


The adults are small, yellow and brown grasshoppers, about 3 cm in body length, with a conspicuous broad, brown stripe laterally through the eyes and extending posteriorly along the tegmina. The distal end of the tibia is dark brown and conspicuous. The underparts are bright yellow, the back pale brown.
Distribution The two species here included are difficult to separate taxonomically and occur throughout the region from India to north Australia and up through S.E. Asia to Japan (CIE map no. A295).

Other species are reported to occur in Africa.
Control A wide range of chemicals are used against grasshopper pests, including DDT, dieldrin, carbaryl, fenthion, diazinon and phosphamidon, but local advice should be sought for use on paddy rice, partly because of the aquatic nature of the habitat and also because of resistance problems with some chemicals (e.g. diazinon).

Fig. 9.46. Oxya sp. (Small Rice Grasshopper); S. China.



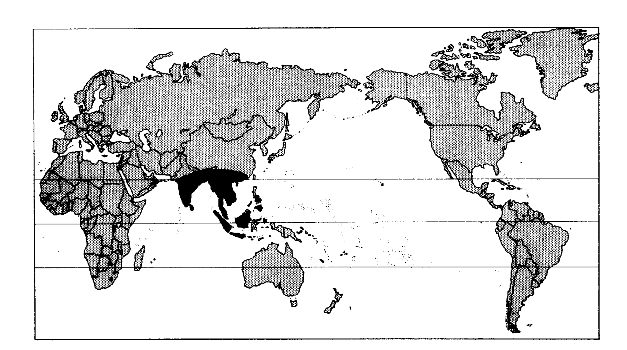


adult on sweet potato leaf

Patanga succincta (L.)

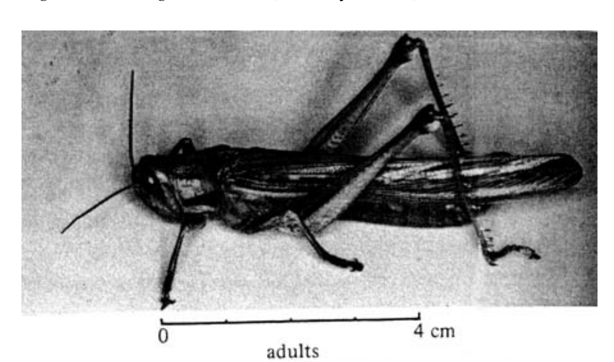
Common name Bombay Locust
Family Acrididae
Hosts (main). Maize and other graminaceous crops.
(alternative). Wild grasses (Gramineae), and some herbaceous crops.
Damage Defoliation by both adults and nymphs; on maize the silks and the soft grains may also be eaten.
Pest status A sporadic pest throughout mainland S.E. Asia, generally confined to higher altitudes in this region. In S. China it is a solitary species found on high altitude grassland with no pest status whatsoever, but in parts of Thailand and India it behaves like a locust and sometimes swarms in enormous numbers, defoliating maize and other crops: in India plagues occurred in 1835–45, 1864–6, and 1901–8.
Life history The breeding biology is that of a typical short-horned grasshopper, with egg pods laid in soft sandy soils. In most parts of its range there is probably only one generation per year.

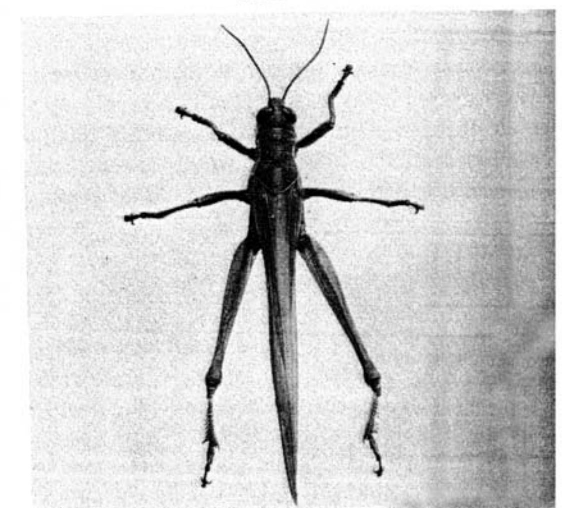
The adult is a large buff and brown-coloured grasshopper, 5–7 cm in body length, with a distinctive buff stripe dorsally on the pronotum extending backwards, and another broad buff stripe on the side of the pronotum. In flight the bases of the hindwings are conspicuously reddish-purple.
Distribution Recorded from S. China through mainland S.E. Asia to India, and Sri Lanka.
Control The usual chemical pesticides effective against grasshoppers will presumably give adequate control if required (page 147).



In 1978–80 this was a major pest in N. Thailand, and was subject to an interesting integrated control programme. Natural predation rates were high, and included an egg parasite (*Scelio* sp.) and egg predators (*Mylabris* spp.). In 1980 peasant labour was employed to hand-catch the locusts, and 80 tons were collected in a few days. Intercropping with soyabean was practised, and at high temperature the locusts left the maize to seek refuge in the shorter legume foliage, where some were destroyed using insecticidal sprays and others were eaten by domestic ducks.

Fig. 9.47. Patanga succincta (Bombay Locust); S. China.





Schistocerca gregaria (Forsk.)

Common name Desert Locust
Family Acrididae
Hosts A very polyphagous pest, and virtually all crops are at risk so far as locusts are concerned, but there is some preference for cereals.
Damage The leaves, and soft shoots, are eaten from the margin inwards leaving irregularly shaped feeding marks. Swarm damage usually results in complete defoliation of the crop.
Pest status A sporadically serious pest in Africa and India; when swarms occur the damage can be devastating over a wide area. The outbreak area is very extensive and extends from W. Africa through the Sahara to Pakistan and India. Typically it can breed in any desert-type area when there is sufficient rain.
Life history The eggs are laid in a hole made by the thrusting ovipositor, about 10 cm deep, in sand, embedded in a frothy mass which hardens to form a tubular egg-pod. Each egg is oval, being 1.2–1.3 mm long by 0.7–0.8 mm broad. Each egg-pod contains 70–100 eggs, and each female may lay several (4–5) pods of eggs. Egg development takes two or more weeks according to temperature.

The first larva is rather vermiform and it has to wriggle up through the egg pod to the sand surface. On reaching the surface it moults and becomes a 'hopper'. Over a period of several weeks the hoppers develop through five instars before they become adult. The hoppers exist in two distinct phases, solitary and gregarious, with differences in colour and behaviour.

The adults are large; male 40–50 mm, and female 50–60 mm, pale yellow or brownish. The elytra are greenish-yellow, translucent, with many brown spots. There are several generations per year.
Distribution It occurs in Africa through the Middle East to India and Pakistan. *Schistocerca cancellata* (South American Locust) is important in southern S. America, and *S. piceifrons* is the Central American Locust
Control The hoppers may be attacked through the use of baits (with aldrin and BHC) as well as dusting, ground spraying and aerial spraying with dieldrin, aldrin, BHC, or carbaryl, parathion-methyl or diazinon; fenitrothion is used now (1988) but not persistant enough.

Against aerial swarms dieldrin, BHC, malathion and DNOC are widely employed.

Barrier spraying with persistent insecticides such as dieldrin can be very successful.

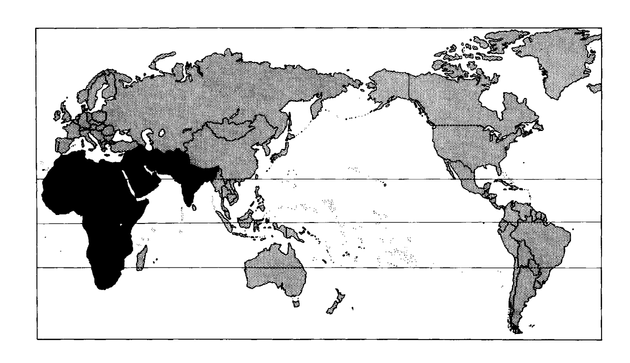
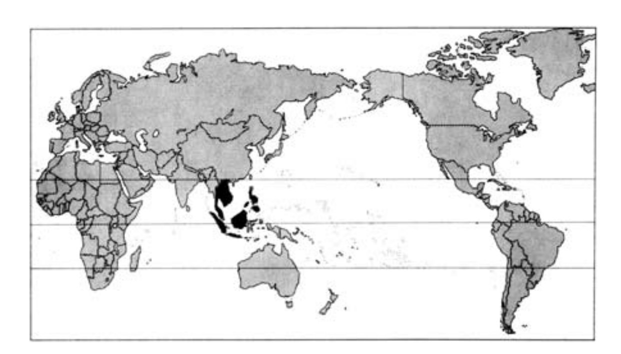


Fig. 9.48. Desert Locust (*Schistocerca gregaria*); Kenya.



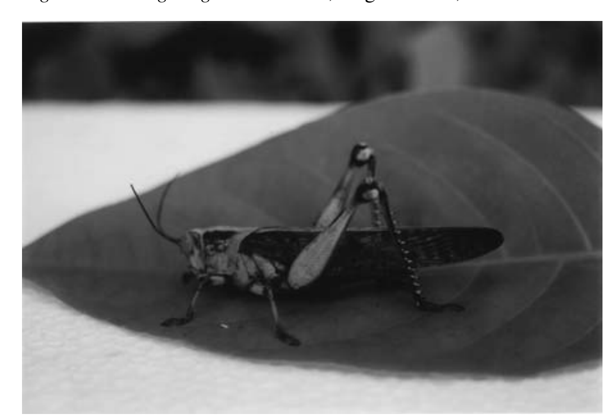
Valanga nigricornis (Burm.)

Common Name Javanese Grasshopper
Family Acrididae
Hosts A polyphagous pest recorded from 35 host crop plants, but most damaging on oil palm, rubber and cocoa, and also on leguminous cover crops; the host range includes a wide range of plantation, tree and cash crops.
Damage Defoliation can be severe and outbreaks over thousands of hectares are recorded in Malaysia - generally only the leaves and shoots are eaten.
Pest Status A regular and common insect in gardens and crops, sporadically a very serious pest throughout S.E. Asia. Other species are pests in Australia and New Guinea.
Life History Univoltine, eggs are laid in a pod of 70–100, buried 5–8 mm in soft sandy soil, and this stage may last for 2–3 months. Nymphal instars number 6 or 7, and the entire life cycle takes 6–8 months. Adults are large green/yellow insects about 57 mm in the male and 73 in the female. Adults are very distinctive with deep rose coloured hindwings. No gregarious phase has been recorded.



Distribution This species occurs throughout Malaysia, Thailand and the Philippines in 18 different subspecies. *V. irregularis* (Australian Coast Locust is a pest in gardens and on some crops in N. and E. Australia. Five other species occur in Papua New Guinea and some Pacific Islands.
Control Contact insecticides have been used to control these pests, either as spot-sprays or blanket treatments – usually methamidophos.

Fig. 9.49. Valanga nigricornis adult; length 60 mm; from Sarawak.



Order ISOPTERA

These are termites, sometimes quite erroneously called 'White Ants'. They are social insects; polymorphic, living in large communities, sometimes in elaborate nests both above and below ground, containing workers, soldiers, and reproductive forms; they have biting mouthparts; two pairs of equalsized wings, with a fracture line near the base where the wings break off; the cerci are very small; metamorphosis is slight or absent; some genera have symbiotic bacteria in the gut which break down the cellulose (wood) eaten by the insect; others use the cellulose to cultivate fungi which are then eaten.

For further information about termites see W.V. Harris (1971).

Family **Hodotermitidae**

These are wood-inhabiting and subterranean species; ocelli and fontanelle are absent; the pronotum is saddle-shaped and narrower than the head; workers are present in some genera.

Family **Rhinotermitidae**

(Wet-wood Termites) Regarded as being a primitive family, they nest in damp dead wood, and tend to be urban rather than agricultural pests; some 37 species are potentially important domestic pests attacking structural timbers and the like. The nest is typically subterranean in dead tree stumps, no mound is built. The fontanelle (opening of the frontal gland) is well developed and the soldiers use the frontal gland as a defensive organ – when alarmed they exude a drop of sticky fluid through the fontanelle. *Coptotermes* is a large genus, with 45 species found throughout the tropics and especially well-represented in Australia and Malaysia. Many species are pests of constructional timber and some attack growing trees and crop plants. All members of this family have the symbiotic micro-organisms in the intestine that enable them to digest the cellulose they eat.

Coptotermes curvignathus is known in Malaysias the Rubber Tree Termite and it usually feeds on living trees which are killed.

Family **Termitidae**

(Mound-building Termites) This is the largest family of termites; all are ground-dwelling species with a wide range of food habits and colony structure; fontanelle is present; the pronotum of workers and soldiers has a raised median anterior lobe; workers are present in all genera. Most species produce the spectacular mounds under which the colony lives; the largest mounds may be 1–2 (up to 5 m) m in height.

Termite Control in 1990

For the first time since the 1940s control of termites is presenting a major problem, worldwide. Resistance to the organochlorine compounds never became established but the use of these chemicals has been restricted on environmental grounds. Finally the manufacturing of these chemicals has ceased, and their use for termite control is now officially discontinued. Sadly, the withdrawl of aldrin, dieldrin, heptachlor, chlordane, etc. was because of chronic overuse in Europe and North America, especially over-wintering seed dressings on cereals. In the tropics there never was the overuse of the organochlorine insecticides, with its consequent environmental damage, and under tropical conditions chemical degradation was more rapid so that persistence was reduced. There are presumably stocks of aldrin and the other chemicals that will continue to be used in the third world for some time to come, for termite control. Generally the present position is difficult for good alternatives are not available. Persistence is the key factor for termite insecticides, and the alternative candidate chemicals degrade too rapidly in the soil to give effective control.

Control is needed for two different types of termite infestation, namely :-

(a) Buildings

(b) Field crops and agroforestry

Nest destruction by application down the entrance/ventilation tunnels can be acheived using a number of different contact insecticides or fumigants.

Building protection involves the application of insecticide in the foundations, and here it is dark, cool and airless so that chemical persistence is enhanced. The chemical most extensively used at the present time in the USA is chlorpyrifos ('Dursban'), but cyhalothrin ('Karate') is being developed for this purpose; isofenphos is also being used. Previously aldrin HCH and dieldrin were the chemicals used For agroforestry, seed-bed protection is not a particular problem, but seedling planted-out usually suffer water-stress and are then vulnerable to termite damage, and they really require protection for up to a year. Experiments using slow-release formulations of phorate and chlorpyrifos have given good protection to *Eucalyptus* seedlings in Africa for up to a year (Wood, *in litt.*) after planting out. Chlordane, heptachlor, were also successful.

Field crop protection is difficult at present for the organophosphate compounds break down in the soil too quickly to give adequate control, and there is revived interest in plant breeding for resistance to termites. Malathion, dichlorvos, and some carbamates have been used with success on field crop infestations in India and Africa.

Hodotermes mossambicus Hagen

Common name Harvester Termite
Family Hodotermitidae
Hosts (main). Many species of grasses.

(alternative). All species of grass appear to be attacked; also a minor pest of cotton.

Damage Numerous conical earth mounds about 10 cm high scattered throughout short grass areas. During the cooler hours of the day many small grey-brown termites can be seen carrying small pieces of grass to holes in the centre of these mounds. Many bare, grassless patches in the vicinity of the mounds.

Pest status A major pest of grassland below 1500 m in parts of Africa, especially during periods of drought or following overgrazing.

Life history The colony consists of a number of separate hives constructed from 0.2 to more than 1 m below the soil surface, interconnected by underground passages. Each hive is a dome-shaped cavity about 0.5 m in diameter; some are full of termites in all stages of development; others are used largely for the storage of cut grass. The hives are connected to the surface by tunnels passing through the centre of conical mounds of loose earth on the soil surface. If the foraging tunnels are not in use they are sealed with mud.

Only the workers are usually seen on the soil surface, these are about 14 mm long, grey-brown, with large heads. They forage at dawn and dusk and at other times in cool weather; they cut and gather pieces of grass and wood, pieces of leaf and herbaceous twigs. The soldiers usually take up positions near the entrance of the foraging tunnels to repel intruders. The soldiers have pale bodies and large dark heads with massive jaws.

Distribution S. and E. Africa.

Control As a tentative recommendation, dieldrin is suggested as an overall spray on the grassland; the application of phorate or isofentos (see page 153) down the tunnels is very effective.

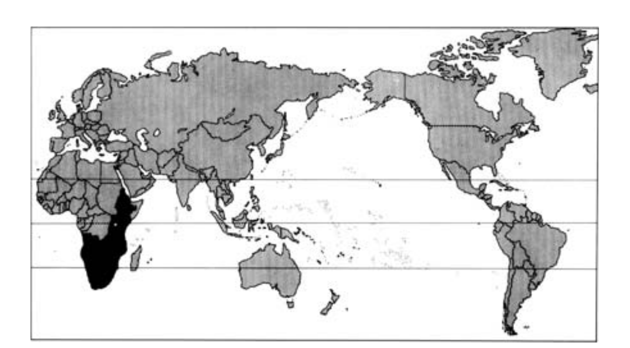
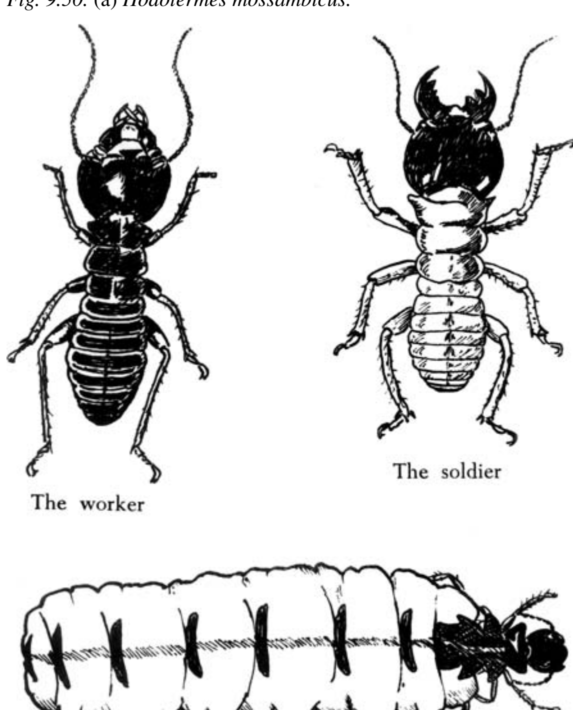
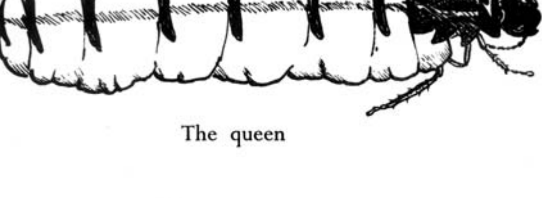


Fig. 9.50. (a) *Hodotermes mossambicus.*





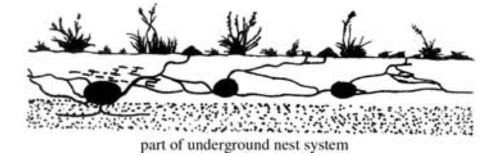


Fig. 9.50. (b) Harvester termite colony in Ethiopia.



Coptotermes spp.
Common name Wet-wood Termites
Family Rhinotermitidae
Hosts These are essentially, polyphagous tropical forest species that usually lives in the moist stumps of dead trees, but have adapted for life under both urban and agricultural conditions. Damage is reported to have been done to forest trees, groundnuts, fruit trees, sugarcane, rice, and other food crops.
Damage On woody plants the termites may construct earth-covered runways, under cover of which they eat the bark away; seedlings may be ring-barked. Roots may be eaten under the ground. Generally old and sickly, or very young, plants are the ones attacked.
Pest status A pest of occasional importance agriculturally, throughout the tropical regions of the world.
Life history The nest is usually in a moist dead tree stump at the edge of forested areas, but structural timber in buildings and bridges is also favoured. It is usually rather small with only a few thousand inhabitants. The wood is eventually honeycombed by a series of tunnels ramifying throughout.

The workers are small, about 4 mm in length, with soft white bodies, and pale yellow round heads with small mandibles. Soldiers are larger, but still rather small, about 5 mm long, with brown heads and slender black mandibles. At the front of the head is the fontanelle through which a white viscous fluid can be extruded when alarmed.

Winged adults swarm periodically during the early evenings of warm wet days in the summer; they are orange in colour, about 8 mm in body length, with hyaline wings of 11 mm.
Distribution The genus *Coptotermes* is found throughout the tropics with 45 species, but is best represented in Australia and S.E. Asia. The species *C. formosanus* is recorded from China, Taiwan, S. Africa, Japan, and Hawaii, and the USA. About half the species are pests of field crops and the other half attack timbers and buildings; a few species do both.

Reticulitexmes in the New World/Asia/Europe
Control Dieldrin was the most effective insecticide when applied appropriately, but now various pyrethnoids are mostly used.

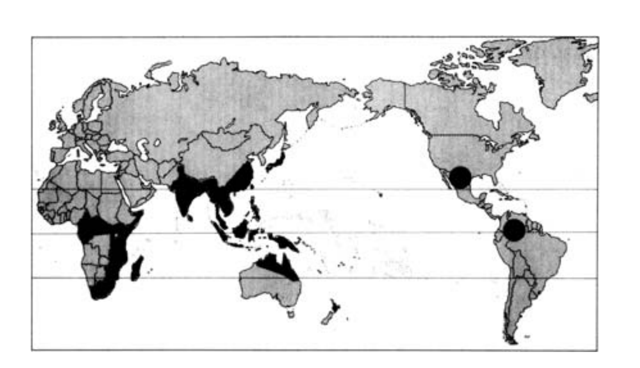


Fig. 9.51. Coptotermes sp. (Wet-wood Termite); S. China.

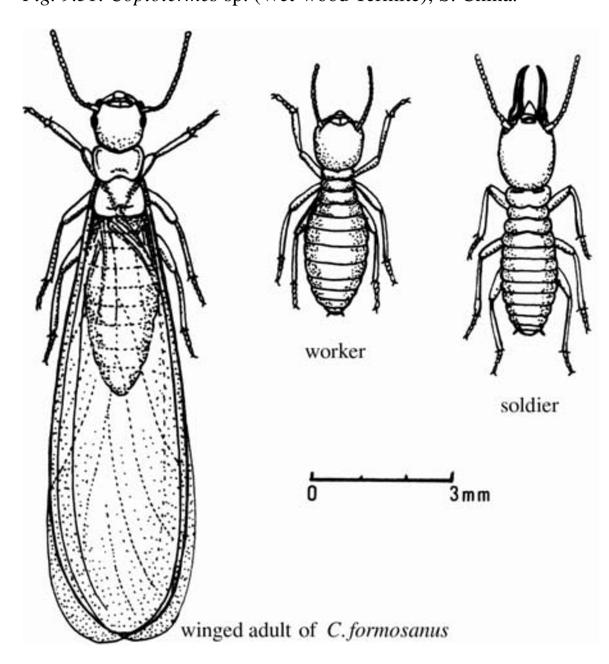


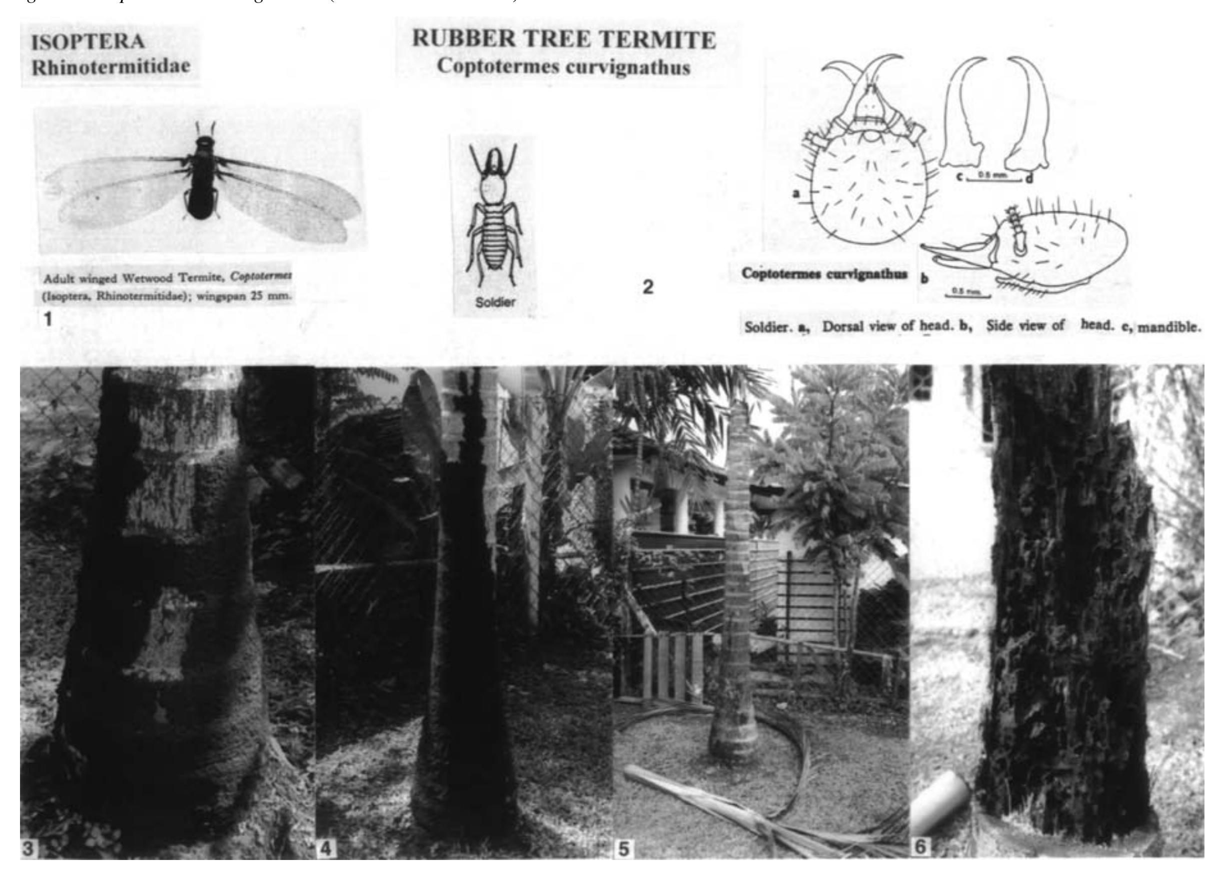
Fig. 9.51. Wet-wood Termite Coptotermes formosanus.



Coptotermes curvignathus Holmgren

Common Name Rubber Tree Termite
Family Rhinotermitidae
Hosts Many wild trees and palms and cultivated rubber, teak, oil palm, coconut, cashew, coffee, citrus, chilli and sugarcane.
Damage An unusual species in that it can attack apparently quite healthy trees, and can kill the host in a matter of weeks. Attacked plants wilt and the trunk and roots are hollowed out by the feeding termites, and the tree will collapse. Storm damage to weakened trees is especially serious.
Pest Status A serious primary pest in many situations in S.E. Asia as the entire tree is killed. In a rubber plantation typically groups of trees are attacked by the one colony of termites.
Life History The nest is usually just below ground in a hollowed out tree stump or tap root and is not at all obvious. Access is provided through a hole in the trunk just above or below ground level. The workers construct a mud casing over the tree trunk and underneath its protection the wood is eaten away. The casing may extend to a height of a metre or more and cover the entire trunk laterally. The primary nest is where the queen lives but there may be a series of subsidiary nests connected by galleries underground attacking other trees. The colony is not large in comparison with some other species but will number at least several thousand individuals.
Distribution Endemic to Malaysia, Borneo, Indonesia, and probably also Indo-China. A similar species *C. testaceus* is damaging to rubber in C. and S. America.
Control Cultural control can be important in establishing new plantations and all dead tree stumps should be removed and all plant debris (trunks, branches, etc.) should be collected and burned. Similarly any infested trees should be destroyed by burning.
Chemical control consists of applying an insecticidal drench to the affected tree base. Contact insecticides such as the organo-chlorines (HCH, dieldrin, etc have been extensively used very successfully in the past but are now often replaced by chlorpyrifos, dichlorvos, malathion and some newer pyrethroids.

Fig. 9.52. Coptotermes curvignathus (Rubber Tree Termite) Sarawak.

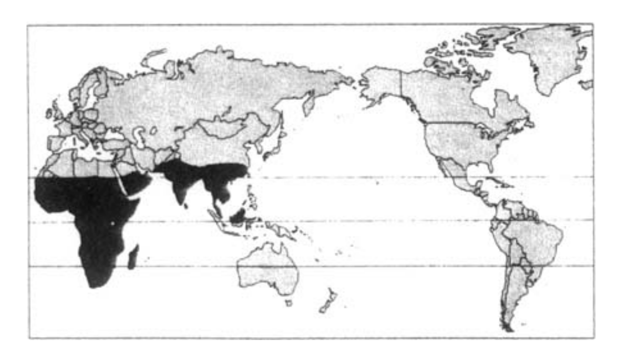


Macrotermes spp.

Common name Bark-eating Termites
Family Termitidae
Hosts These are polyphagous general feeders found throughout the Old World Tropics and they occasionally cause damage locally to a wide range of crops, such as, coconut, coffee, cocoa, clove, groundnuts, rice, sugarcane, fruit trees and forest trees.
Damage These are the termites that build large spectacular mounds in Africa so their presence is generally obvious in an area. Typical damage is to cover tree-trunks, or plant stems, with covered runways (sometimes even sheets) composed of plant fragments, soil and saliva, and underneath the protecting cover the termites gnaw away the bark. Small plants may be completely killed, and trees may be ring-barked. Sometimes root damage subterraneously may be serious. The collected plant material is taken back to the nest for construction of fungus gardens.
Pest status. A widespread, but only sporadically serious, pest throughout tropical Africa and Asia, recorded attacking a wide range of crops.
Life history This family is referred to as containing the subterranean, mound-building and bark-eating termites. They possess no symbiotic intestinal micro-organisms and they utilize the collected plant cellulose by constructing underground fungus gardens in special chambers; the honeycombed fungus garden base is innoculated with a special species of fungus (*Termitomyces*) and the mycelium spreads over the cellulose 'garden'. At intervals along the hyphae are found white, globular swellings known as bromatia and it is on these bromatia that the termites feed.

The young are cared for by small workers in the nest, whereas the larger workers go out and forage for food, partly through underground tunnels and partly on the soil surface and in the litter, where they are protected from predation by the large aggressive soldiers.

The mound of *M. bellicosus* in Africa may be 1–3 m in height, but in Malaysia *M. carbonarius* builds a mound no higher than 1 m, and in S. China the local *M. barneyi* has no mound at all, the nest being entirely subterranean, presumably due to the cooler climatic conditions prevailing there.



Colony size is large, up to one million as more inclividuals.

The adults are pale brown in colour, about 8–15 mm in body length, with wings 17–30 mm long, hyaline but with a yellow tinge, and they swarm periodically in vast numbers.

Each colony lasts for several years (3–8 years) but are not as long-lived as might be expected.
Distribution This genus occurs as about 7–10 species throughout tropical Africa and tropical Asia, extending as far north as S. China.
Control If control is required then aldrin and dieldrin, either in baits, or applied directly to the nest holes, were the most effective pesticides for many years, but now other chemicals are used (p. 153).

Fig. 9.53. Macrotermes sp. Winged adult and nest mound (1 metre) in Penang.

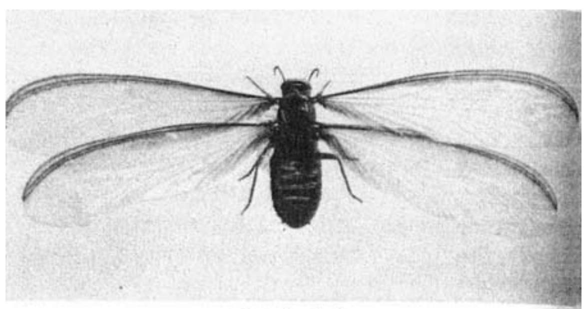




Fig. 9.54. (a) Nest mound of *Macrotermes* sp. in Ethiopia,

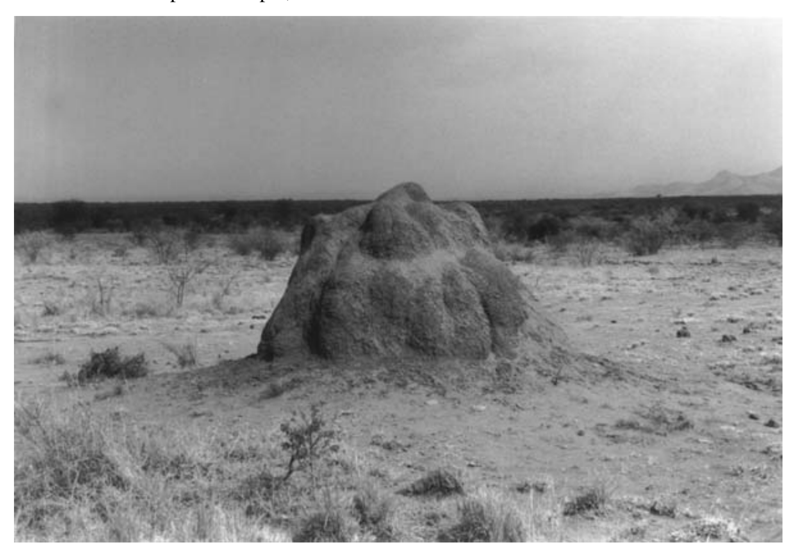
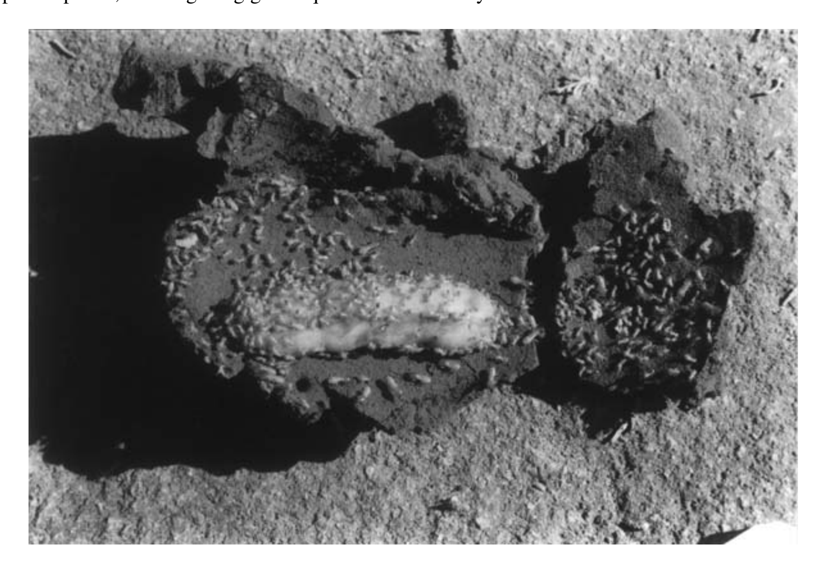


Fig. 9.54. (b) Royal capsule opened, showing the gigantic queen surrounded by workers and soldiers.



Odontotermes spp.

Common name Bark-eating Termites
Family Termitidae
Hosts A polyphagous pest recorded attacking a wide range of crops, both as seedlings and as grown plants; but sugarcane, coconut and tea are attacked by several species. Date palm
Damage Some damage is underground to the roots and underground stem of the plants; some is the typical bark-eating under sheets of earth/wood particles; seedlings may be completely destroyed. Tea bushes may be ring-barked. Palms may be tunnelled internally.
Pest status A sporadic pest throughout tropical Africa and Asia, locally important on a wide range of crops. Water-stressed or sickly plants are more often attacked than healthy plants.
Life history Colonies of *Odontotermes* are generally smaller than those of *Macrotermes*, but according to W.V. Harris (1971) this genus is probably the dominant soil-dwelling termite in terms of actual numbers. The nest mounds are also generally smaller.

The Crater Termite (*O. badius*) is a rather different species from most of the rest and so has been dealt with separately.

As with other members of the Termitidae this is a fungus-growing species that has the typical fungus gardens in underground chambers joined by a series of narrow tunnels.

Adults are slightly smaller than *Macrotermes* spp., most being about 7–13 mm in body length with wings 15–28 mm in length; the wings of most species are quite dark brown in colour.

Healthy, intact, vigorous plants are generally not damaged by most termites, but if water-stressed or sickly in any way, or physically injured, they are more likely to be attacked. Many *Odontotermes* species gain access to woody plants, such as tea, through the dead ends of pruned branch stumps from which they may invade the living tissues. Often attack palms by penetrating roots and tunnelling up inside the trunk
Distribution W.V. Harris (1971) lists a total of 23 species of *Odontotermes* from tropical Africa throughout mainland S.E. Asia and India; all recorded as pests of various crops.
Control As with other termites, if control is required then dieldrin applied down the nest entrances is still the most effective pesticide; chlordane, heptachlor are widely used.

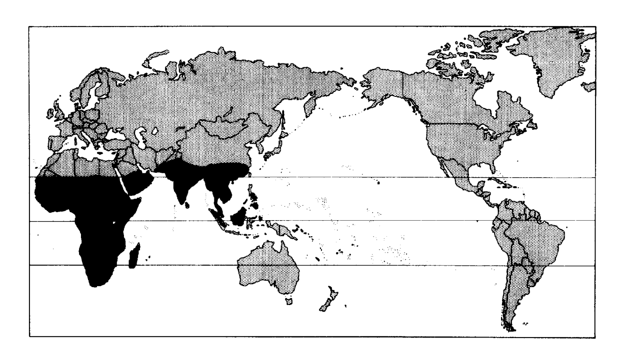
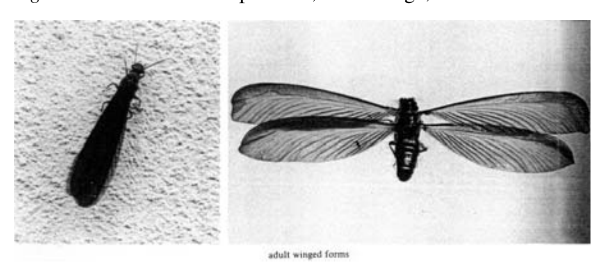


Fig. 9. 55. Odontotermes sp. adults, and damage; S. China.







Odontotermes badius (Haviland)

Common name Crater Termite
Family Termitidae
Hosts (main). Seedlings of various crops, and grasses.
(alternative). Sugarcane, and often found in the mulches used in coffee, tea, and banana plantations.
Damage The nest is characterized by a series of low mounds through which a number of wide vertical shafts open to the exterior. The shafts are ringed at the top with crater-like earthen collars.
Pest status Not a primary pest of growing crops except in very dry years when some seedlings may be attacked. Lawns and flower beds are badly disfigured by the nests.
Life history The Crater Termite is another typical fungus-growing species. The colony is established by a pair of night-flying winged reproductives. They shed their wings and build a cell underground, which is later expanded. When the colony is well established, vertical shafts are built which one-by-one erupt to the exterior at the start of the rainy seasons. A large nest may be 2 m in diameter and be covered with 15 or more craters of various diameters. The nest contains a large number of fungus gardens.

The worker termites are pale-bodied insects about 4.5 mm long, often with large, pale brown heads. In rainy weather they can often be seen at work adding soil to the crater rims at the top of the vertical shafts. The soldiers are about 6 mm long with very large, brown heads and conspicuous black jaws. The mature queen termite is enormously distended in the abdomen and may be 10 cm or more long. Winged reproductives are produced in very large numbers in rainy seasons and they swarm out of the colony through the vertical shafts.

The adult female has an egg-laying capacity of one egg every two seconds.
Distribution Most parts of tropical Africa.
Control Contact insecticides in solution, to be poured down each of the vertical shafts, preferably during the rainy season.

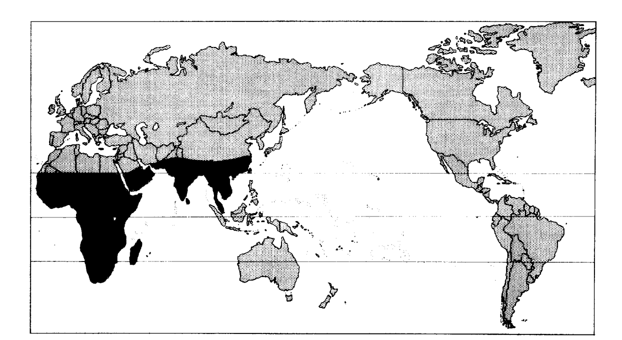
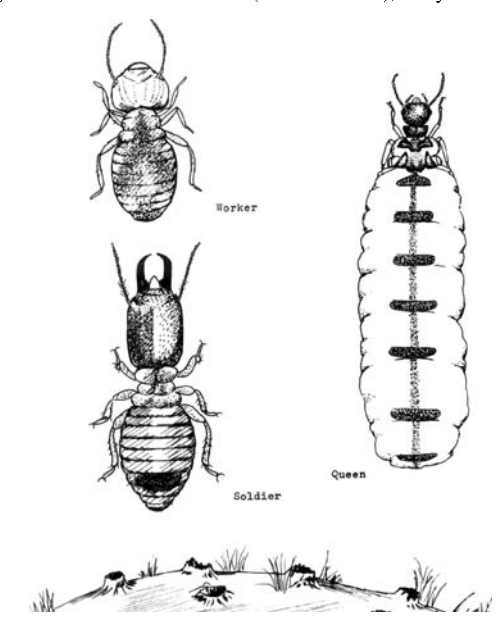


Fig. 9.56. Odontotermes badius (Crater Termite), Kenya.



Pseudacanthotermes militaris (Hagen)

Common name Sugarcane Termite
Family Termitidae
Hosts (main). Sugarcane
(alternative). Often found among fallen leaves under mango trees, where they make their characteristic 'rattling' sounds. Also on tea and tung.
Damage Poor germination of sugarcane setts; mature cane is encrusted with earthen tunnels; stalks are often felled when nearing maturity.
Pest status A major pest of sugarcane in Kenya; elsewhere damage is only sporadic.
Life history The mature colony is marked above ground level by a conical mound up to 1 m in height. If the nest is dug out, the sponge-like fungus gardens can be found. The chewed-up wood and pieces of vegetable matter are built up into the fungus gardens on which special species of fungus are cultivated; the termites then feed on the fungal mycelium and bromatia.

The worker termites are pale-bodied insects about 4 mm long with large, brown heads. The soldiers are also pale, about 6 mm long and have very large heads with conspicuous pincer-like jaws. The queen termite has a typically enormously distended abdomen and may be 5 cm or more in length. She lives with her royal male in a special cell near the centre of the nest. Winged reproductives are produced in large numbers in the rainy seasons. Unlike most other species of termites these fly in the day-time and can often be seen swarming round the tops of tall trees.
Distribution Kenya, Malawi, and Uganda.
Control The planting material should be dipped in a mixture of contact insecticide in water, prior to planting.

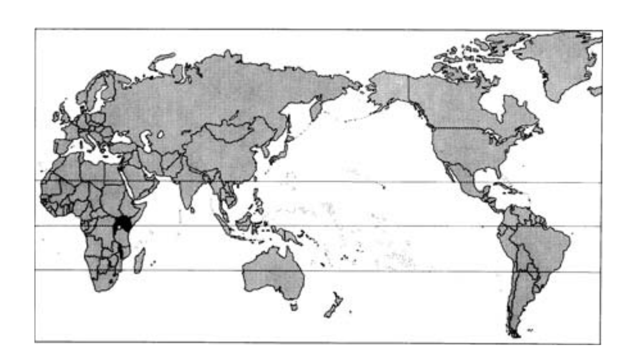
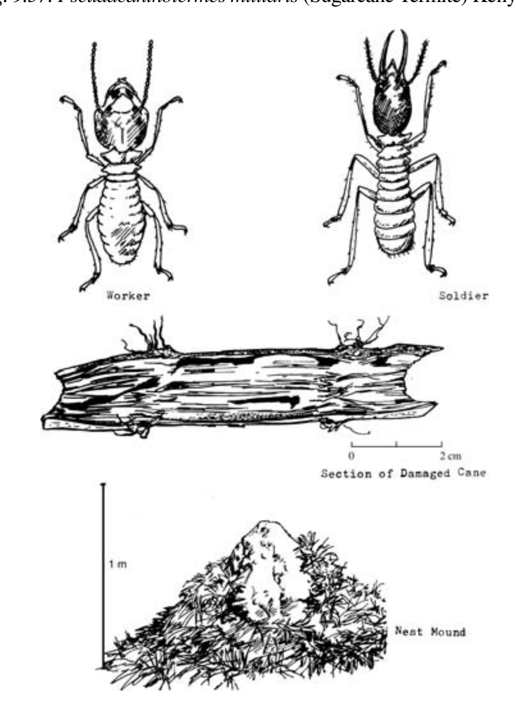


Fig. 9.57. Pseudacanthotermes militaris (Sugarcane Termite) Kenya.



Order **HOMOPTERA**

These are plant bugs often referred to as a separate suborder of the order Hemiptera, but here for convenience is regarded as a separate order. Two pairs of wings are usually present, but the anterior pair is uniformly thickened, and the wings are held roof-like over the body; head more or less deflexed; metamorphosis usually incomplete, but sometimes complete in males; they have piercing and sucking mouthparts, and are sap feeders.

Family **Cercopidae**

(Froghoppers, or Spittle Bugs) They are characterized by large stout hind tibiae bearing a terminal ring of stout setae. The nymphs of some species are subterranean, the rest are found on grasses and various herbaceous shrubs or trees; they are immersed in a froth of 'spittle' which serves to protect the soft body from desiccation and predation. The adults are capable of jumping considerable distances. Many species are pests of sugarcane in S. and Central America.

Family **Cicadellidae (= Jassidae)**

(Leafhoppers) A large family of bugs, second in abundance only to the Aphididae. They are slender, small insects, usually tapering posteriorly; thin tapering antennae; they jump very readily when disturbed; the hind tibiae are elongate and with a series of regularly spaced stout setae along the anterior edge. Eggs are usually laid embedded in the plant tissues. Many species are virus vectors. There are many important pest species. Some species are only found on Gramineae, but others infest trees and may be fruit pests.

For a review of the bionomics of leafhoppers see De Long (1971).

Family **Tettigometridae**

These are superficially very like jassids, but with fulgoroid characteristics also; the antennal flagellum is segmented.

Family **Delphacidae (= Araeopidae)**

(Planthoppers) The characteristic feature of these insects is the large, mobile, serrulate apical spur on the hind tibiae; the antennae are very short, with a terminal arista. They are vectors of various plant viruses, mostly on Gramineae and cereal crops.

Family **Fulgoridae**

(Lantern Bugs) A small tropical family, not important as pests, but widespread. The anterior part of the face is drawn out into either a tapering 'snout' or a large bulbous shape rather like a peanut. They are large in size, often 5–6 cm in length.

Family **Flattidae**

(Moth Bugs) A small group, tropical in distribution, moth-like in appearance, gregarious in habits, with nymphs producing large quantities of wax. Many species seem to prefer hosts in the Sterculiaceae. Conspicuous insects of the tropical rain forests, but seldom serious pests.

Family **Ricaniidae**

(Ricaniid Planthoppers) Another group of fulgoroid planthoppers with expanded forewings, but held laterally at rest, and not moth-like. Widespread in the tropics as minor pests on many different crops and ornamentals.`1

Family **Lophopidae**

A small group of tropical fulgoroids with an anterior snout-like process (being an extension of the frons) with one to three longitudinal carinae; the antennae are very short with a terminal arista.

Family **Psyllidae**

(Jumping Plant Lice) These bugs are about the size of aphids but resemble small cicadas; they are very active but not capable of sustained flight; the wing venation is rather simple; nymphs are typically flattened with distinctly flattened wing buds; the antennae are fairly long, simple, and segmented; the female has a short curved ovipositor; the nymphs secrete quantities of honey-dew, and sometimes waxy filaments. Some species are pests of fruit trees, others are pests of ornamental trees.

Family **Aleyrodidae**

(Whiteflies) These are tiny, delicate, usually white, moth-like bugs, sometimes with dark or mottled wings; the whiteness is produced by a waxy dusting; the nymphs and pupae are characteristically oval-shaped and scale-like with a number of long filaments; the first nymphal stage is mobile, but after the first moult both legs and antennae are lost; honey-dew is excreted by all stages, but particularly by the nymphs.

Family **Aphididae**

(Greenfly, Plant Lice) The most important group of plant bugs, but more adapted for life in the temperature zones than the tropics; they have peculiar modes of development, and pronounced polymorphism; often parthenogenetic or only seasonally sexual; in the tropics most reproduction appears to be entirely parthenogenetic; the rate of reproduction may be quite phenomenal; they are found on the roots of plants as well as leaves, shoots and stems; sometimes galls are formed; all species have conspicuous cornicles or siphunculi; production of honey-dew can be quite copious, and there are often ants in attendance. They are very important vectors of plant viruses, and many species are plant pests on a wide variety of crops.

Useful reference papers on Aphididae are Eastop (1961; 1966) and Van Emden *et al*. (1969).

Family **Pemphigidae**

(Woolly Aphids) A small family, recently separated off from the rest of the Aphididae; they produce vast quantities of

waxy filaments covering most of the body; the siphunculi are small and slit-like.

Family **Margarodidae**
(Fluted Scales, etc.) The females of this family have distinctly segmented bodies, usually covered with a waxy secretion, often in the form of pearl-like waxy scales which are collected as 'ground pearls' in S. Africa and the Bahamas and strung into necklaces; legs and antennae are well developed and simple eyes are present; the adult male has wings, the simple ten-segmented antennae and compound eyes. They can sometimes be mistaken for mealybugs.

Family **Lacciferidae**
(Lac Insects) A tropical group with highly degenerate females which are legless and have a globular body enclosed in a dense resinous cell. *Laccifer lacca* is cultivated in India and China as a source of shellac; other species are crop pests in India and S.E. Asia, mostly on species of *Citrus*.

Family **Orthezidae**
A small group of species mainly confined to America and the Palaearctic region. Females of this family show rather distinct segmentation of the body, which is covered with white waxy plates; legs and antennae are normal; and simple eyes are present.

Family **Pseudococcidae**
(Mealybugs) Females are usually elongate oval with a distinct segmentation and generally covered with a mealy or filamentous waxy secretion, often extended into lateral and terminal filaments; legs are well developed, antennae less so. Some species are subterranean; others make galls. The males are small two-winged insects with long filamentous antennae and wings with very reduced venation. They are often associated with ants, particularly the root-inhabiting species, for the honey-dew they excrete. Some species transmit viruses.

Family **Coccidae (= Lecaniidae)**
(Scales, Soft Scales or Naked Scales) A large family; the females show considerable diversity of form; body segmentation is obscure, and the integument may be naked or covered with wax; the degree of development of antennae and legs varies considerably; the scale is always firmly fixed to the integument of the insect, and is not detachable. Honey-dew is usually excreted, and these insects are mostly attended by ants. There are many important pest species.

Family **Asterolecaniidae**
(Star Scales) A small family of scales separated off from the others on rather esoteric characters, but the tiny star-shaped scale is an obvious character.

Family **Diaspididae**
(Armoured Scales) A large family in which the adult female has lost the legs, and antennae are either lost or vestigial. The hard waxy scale is produced by the female, but is not attached to her body (as in the Coccidae); the scale may be circular, oval or very elongate, and the adult scale also comprises the scales of the nymphs. In some cases the scale is so thin as to be quite translucent. There are many important pest species. Honey-dew is normally not produced by these species.

Tomaspis spp.
Aeneolamia spp.

Common name Sugarcane Spittlebugs
Family Cercopidae
Hosts (main). Sugarcane.
(alternative). Many wild grasses and sedges.
Damage The feeding of adults on the leaves is the main source of damage – root feeding is generally not regarded as serious. Enzymes in the saliva cause necrosis of the plant tissues. In heavy attacks the leaves yellow, then brown, finally wilting and dying, and the plant becomes stunted. Necrotic spots develop round the feeding punctures; over one to three weeks the necrosis spreads longitudinally to form streaks ('froghopper blight'). Uncontrolled infestation can reduce the sucrose content by 30–70%
Pest status Although cercopids are richly represented throughout the tropics, they are common and important pests of sugarcane only in the New World.
Life history Eggs are laid both in the soil and in plant tissues; *Aeneolamia* spp. usually lay most of their eggs in the soil and the larvae feed on the roots of the cane. The eggs are spindle-shaped; many species of Cercopidae have a diapausing egg stage. Incubation takes 2–40 weeks; a moist atmosphere is required for egg development.

The nymphs are characterized by their production of a frothy spittle mass, or 'cuckoo spit', in which they are enveloped. The spittle undoubtedly protects the soft-bodied nymph from desiccation. Some nymphs feed on the leaves of the cane and most are on the roots. There are five nymphal instars in most species. The life-cycle takes about two months.

The adults of many Cercopidae are distinctly coloured – yellow, red and black, etc. *Tomaspis* species are generally red and black, strong fliers and jump well.

Generally 2–4 generations per year.
Distribution West-Indies, C and S. America.

Locris and a few other cercopids are found in Africa, but *Tomaspis* (4 spp.), *Aeneolamia* (14 spp.), and *Delassor* (4 spp.), and a few smaller genera are all confined to S. and C. America and the W. Indies.
Control Dusts of γ-BHC, dieldrin, phorate, toxaphene and carbophenothion applied to the cane stools to control the root-feeding nymphs. Adults are sprayed or dusted by drift dusting or from the air with γ-BHC, DDT, carbaryl and phosmet, malathion, omethoate, triazophos, quinaltos.
The threshold for spraying is generally 5 adults/100 canes (first brood) and 50 adults/100 cane stems for later broods.

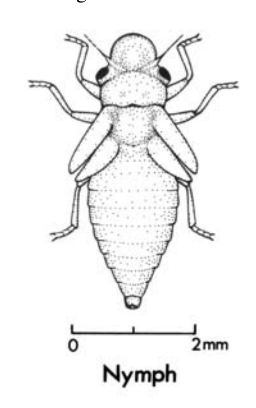
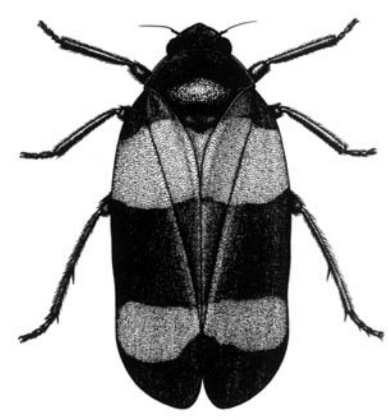




Fig. 9.58. Sugarcane Spittlebug (*Tomaspis* sp.), adult and spittle mass on geranium roots in Ethiopia.



Pyrilla perpusilla Wlk.

Common name Indian Sugarcane Leafhopper
Family Lophopidae
Hosts (main). Sugarcane

(alternative). Millet, wheat, maize, and other species of Gramineae, and some dicotyledons.

Damage Damage consists mainly of sap removal from the plant by the feeding of the nymphs and adults.

Pest status Not a serious pest, but various lophopids are of wide occurrence on crops and plants in the tropics.

Life history The eggs are white, ovoid, 1.0 × 0.5 mm, and are laid almost touching on the leaf in two to four irregular rows, covered with a white waxy secretion. Each batch contains 30–50 eggs. Incubation takes 6–18 days.

After 3–4 hours the nymphs disperse; feeding is most frequent on the lower leaf surface. Honey-dew is excreted in some quantities, and many ants are often in attendance; sooty moulds are also common.

There are five nymphal instars, taking a total of 5–20 weeks for completion, though eight is more usual.

The adults are not strong fliers, but they jump readily. They are 7–8 mm long, pale brown with conspicuous veins in the forewings and scattered tiny dark spots.

The complete life-cycle normally takes from 40–55 days, but in winter development is more prolonged.

There are usually 3–5 generations per year.

Distribution Pakistan, India, Sri Lanka, Afghanistan, Burma, and Thailand (CIE map no. A151).

There are two species of *Pyrilla* found in India and Sri Lanka, but 15 subspecies are recognized.

Control Control is seldom required.

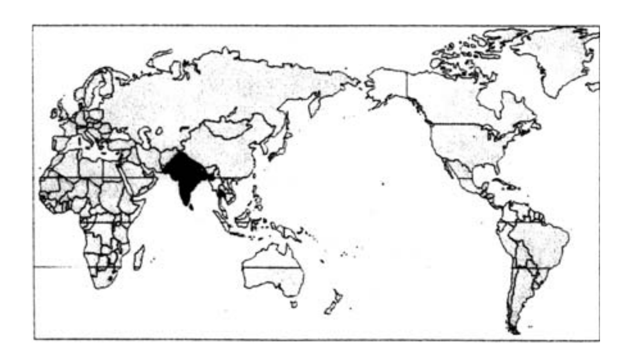
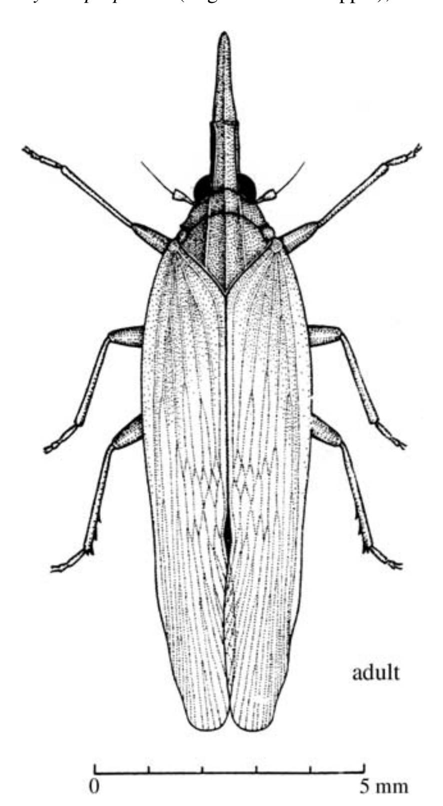


Fig. 9.59. Pyrilla perpusilla (Sugarcane Leafhopper); India.



Diaphorina citri (Kuway.)

Common name Citrus Psylla
Family Psyllidae
Hosts (main). *Citrus* species.
(alternative). Other species of Rutaceae, mostly wild.
Damage Buds and soft young shoots are attacked by the nymphs, leaves become distorted and curled; honey-dew production leads to sooty mould infestation. Badly damaged leaves die and fall, and defoliation of branches can occur. It is thought that the saliva of the nymphs is probably toxic to produce such distortion. Adults do little damage.
Pest status An occasionally serious pest on *Citrus*, especially on young or newly grafted plants.
Life history Eggs are laid, usually in the spring, inside the young, folded leaves in the buds, or in leaf axils. Each female may lay up to 800 eggs during her two-month life. Nymphs hatch after about five days, and after four instars become adult.

Adults are small, about 2.5 mm in length, with pale brown wings having a broad pale stripe along the centre.

The life-cycle takes about 20–40 days according to temperature, and there may be up to nine generations per year.
Distribution From Pakistan and India through S.E. Asia to S. China, Philippines, and Indonesia; one record from Saudi Arabia; also from Mauritius and Reunion; and S. America (Brazil) (CIE map no. A335).
Control Chemical control should only be applied at periods of flush growth, and is usually only required on young trees; dimethoate is usually successful, but should not be used on rough lemon trees or on non-budded rough lemon stock.

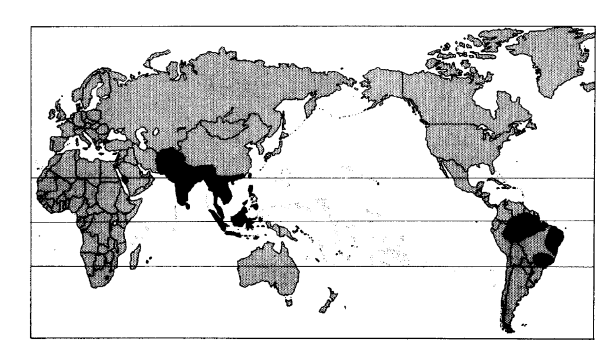
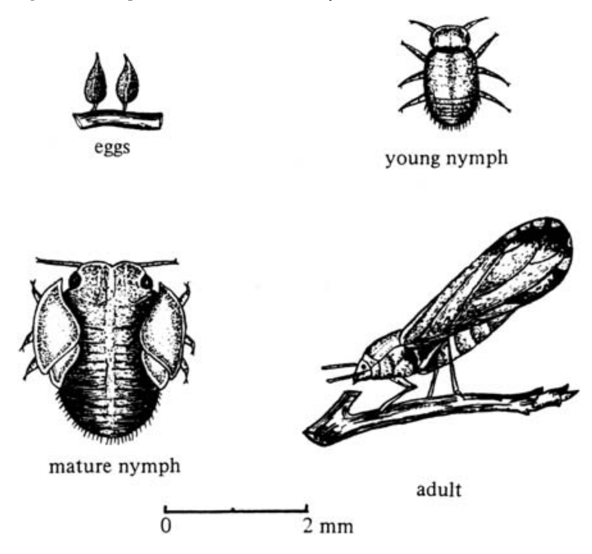


Fig. 9.60. Diaphorina citri (Citrus Psylla); India (Butani).



Psyllid pests (Homoptera; Psyllidae)

Psyllids, sometimes called 'suckers', may either be regarded as constituting a single large family (*sensu stricta*) of about 2000 species, or else about eight closely related families (*sensu lato*). Both adults and nymphs feed by stylet-insertion, usually into the phloem, on the foliage of Dicotyledones mostly. Most species are narrowly host-specific, being either monophagous or oligophagous. They transmit a number of viruses, bacteria and mycoplasms which cause plant diseases. Many species are gall-forming, presumably through cecidogenic chemicals in the saliva. Most galls are formed by feeding nymphs but some adults cause plant distortion by feeding, or by oviposition. Many nymphs produce terminal waxy filaments, sometimes in very large quantities, and most produce honey-dew.

Certain plant families appear to be favoured as hosts, and these include the Malvaceae, Moraceae, Lauraceae, and Sterculiaceae. The hosts include almost equally trees, shrubs, and herbaceous plants. The group is equally well represented in both the temperate and the tropical regions. About a dozen species are crop pests of some importance, and others occur on ornamentals and forest trees. The majority of pest species are free-living and feed on actively growing plant tissues, but most produce some host growth distortion, if not an actual gall.

In the tropics breeding is continuous and up to ten generations per year may occur. Temperate species are mostly univoltine, and most overwinter in the egg stage, but a few have up to three or four generations annually and some overwinter as adults.

Most psyllid populations are kept in check by high levels of natural parasitism and predation, but sometimes chemical control is needed, and in places resistance to various organophosphorous compounds is established.

Temperate species of some importance as crop pests include:

Paratrioza cockerelli Sulc. – (Potato Psyllid of N. America) causes leaf-rolling and foliage distortion; on potato and tomato.

Psylla pruni (Scopoli) – on *Prunus*; throughout Europe, UK, Georgia, Caucasus and Irkutsk.

Psylla pyri (L.) – (Pear Psyllid) restricted to pear as host; found in Europe (not UK) from S. Fennoscandia to Italy and the USSR (Crimea) (CIE map no. A.155).

Psylla pyrisuga Förster – also on pear in Europe, UK, Russia and Japan.

Trioza alacris Flor – (Bay Leaf-roll Psyllid) causes red galls by the rolling of the leaf edge on bay; occurs in both UK and Western Europe.

Trioza apicalis Förster – (Carrot Psyllid) this European species also occurs on potato and parsnip, and causes leaf-curl, the heavier infestations causing most foliage distortion.

Trioza brassicae Vasil'ev – (Brassica Psyllid) recorded from *Brassica* spp. in Russia.

Trioza nigricornis Förster – a truly polyphagous species recorded from 24 plant species in 11 families, although some records are dubious. Distribution in Europe (not UK) from Sweden to Spain, Turkey and the USSR.

Trioza trigonica Hodkinson – probably from carrot, in Europe and the Mediterranean Region.

Trioza tremblayi Wagner – Italy; from onions and some other hosts, probably quite polyphagous.

Trioza diospyri (Ashmead) – (Persimmon Psylla) on persimmon; USA.

Trioza erytreae (Del G.)

Common name Citrus Psyllid
Family Psyllidae
Hosts (main). *Citrus* spp.
(alternative). Various species of wild Rutaceae.
Damage The leaves are conspicuously pitted, the pits opening on to the lower leaf surface. In severe attacks the leaf blades are cupped or otherwise distorted and yellow in colour, especially when young.
Pest status A very common but usually minor pest of mature *Citrus* throughout Africa; more important on nursery stocks, since growth may be checked and the plant badly disfigured.
Life history The eggs are elongate pear-shape, and about 0.3 mm long; usually laid on the edges, or main veins, of very young leaves, anchored to the leaf blade by a short appendage. Hatching takes 5–6 days.

When the scale-like nymph hatches it walks about for a short period and then settles down and starts to feed on the underside of a soft young leaf. Once settled, it does not move again unless disturbed; at the feeding site a pit forms as the leaf expands, the pit increasing in size as the nymph grows but never enclosing the insect completely. Leaves with many pits curl up. Nymphs are yellow with two red eyes, but may turn brown if parasitized. There are five nymphal instars, and the whole nymphal period occupies 2–3 weeks.

The adult is aphid-like, about 2 mm long, with long transparent wings. It is green when it first emerges but later turns brown. Females may live for a month and lay 600 eggs.
Distribution Tropical Africa, mainly on the eastern half; Cameroons, Zaire, Ethiopia, Sudan, E. Africa, Madagascar, Mauritius, Rwanda, Malawi, Zimbabwe, Zambia, S. Africa, and St Helena (CIE map no. A234).
Control Control measures should only be applied in periods of flush growth. Treatment of mature trees is not usually economic. Young trees can be sprayed with dimethoate as a full-cover spray taking particular care to wet the flush leaves.

Dimethoate should not be used on rough lemon trees or on non-budded rough lemon stock.

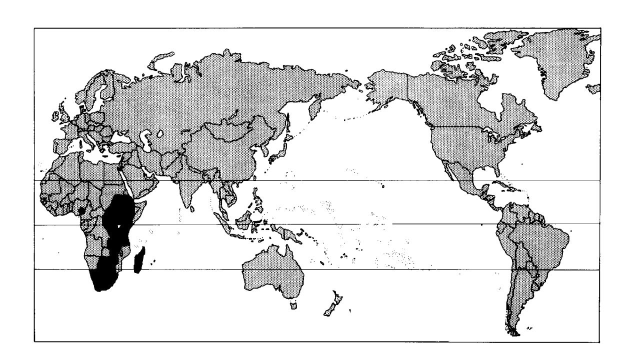
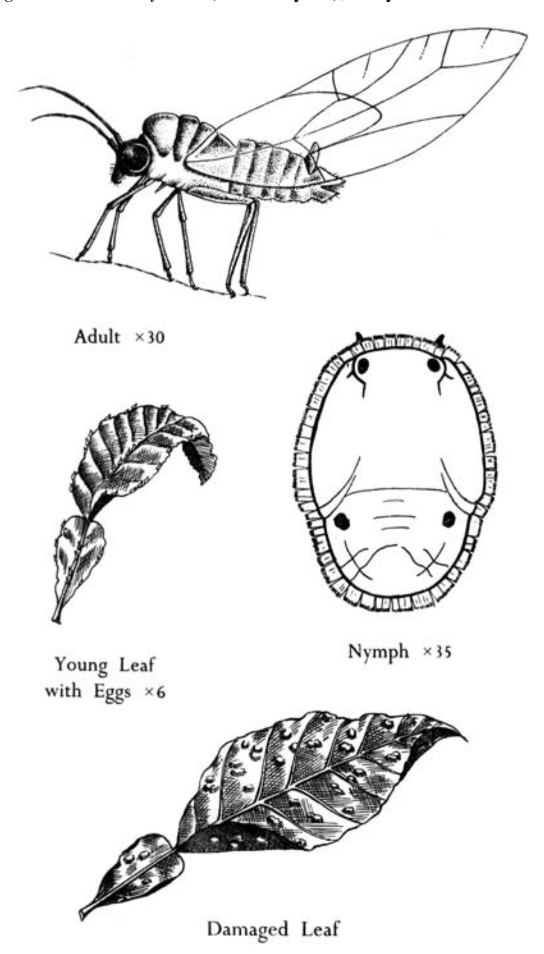


Fig. 9.61. Trioza erytreae (Citrus Psyllid); Kenya.



Aleurocanthus woglumi Ashby

Common name Citrus Blackfly
Family Aleyrodidae
Hosts (main). *Citrus* spp.
(alternative). Coffee, mango, etc. Polyphagous.
Damage Groups of shiny, black, scale-like insects on undersides of leaves. The upper sides of the leaves may have spots of sticky honey-dew or be covered with sooty mould.
Pest status A serious pest in several areas on *Citrus*, and a pest of coffee in the New World.
Life history The eggs are yellowish when first laid but darken to black before hatching. They are elongate oval in shape and about 0.2 mm long. One end is anchored to the leaf by a short appendage, the other tending to be raised from the surface. Batches of 30 or more eggs may be found on the undersides of leaves usually arranged in a spiral. They hatch after about 10 days.

After hatching the larva moves only a very short distance before settling down and starting to feed. There are four nymphal instars; they are all scale-like, shiny black, conspicuously spiny, and bordered by a white fringe of wax. The last instar, the so-called 'pupa', is about 1.5 mm long. The total nymphal period takes 50–100 days, according to temperature.

The adults are tiny moth-like insects, generally black, but with some white markings at the edge of the wings. The body is dusted with a bloom of grey wax. Females are about 1.2 mm long; males 0.8 mm.
Distribution Tropical Asia, S.E. Asia, E. Africa, S. Africa, India, Seychelles, C. America, Ecuador and the W. Indies, S. USA, (CIE map no. A91). The closely related *A. spiniferus* is found in parts of Africa and Asia.
Control If new nursery stock is brought into an orchard which is still free from Blackfly the plants should be completely defoliated and dipped into a solution of dimethoate before planting.

In parts of Kenya the aphelinid wasp *Eretmoceros serius* has been introduced and has become established and gives excellent control.

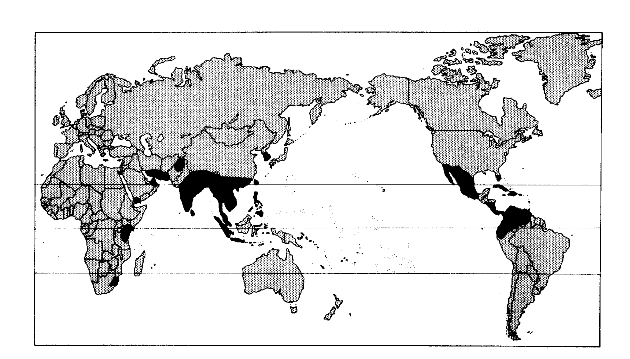
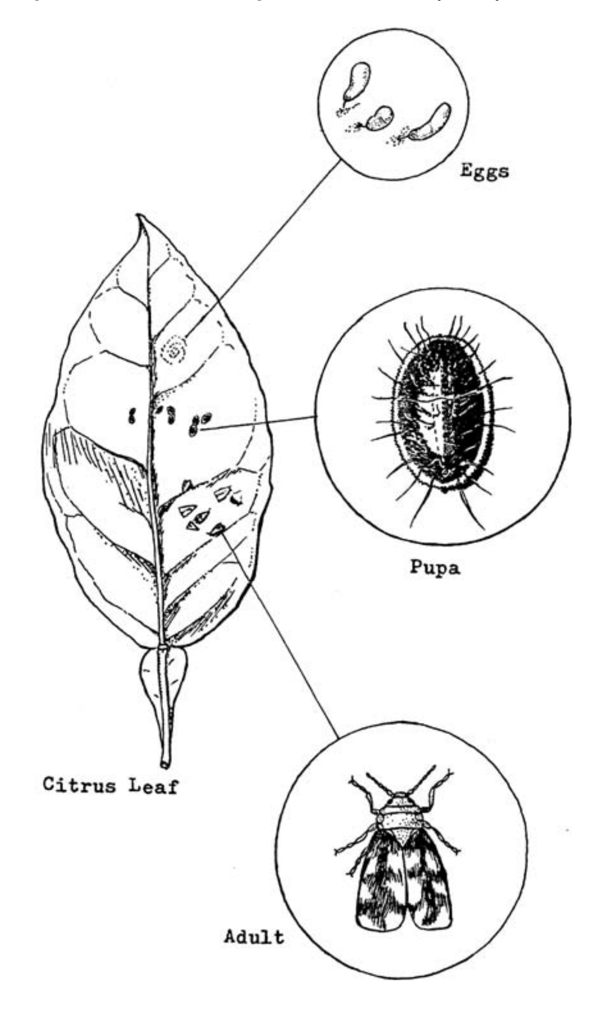
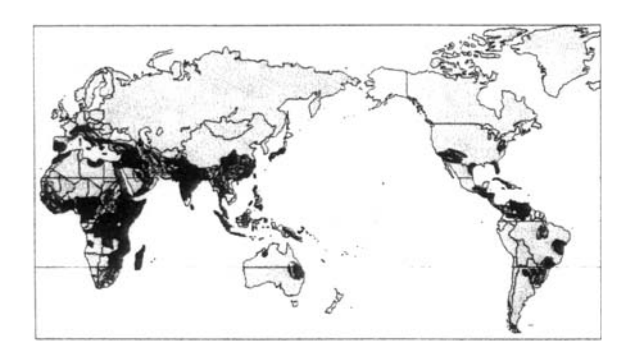


Fig. 9.62. Aleurocanthus woglumi (Citrus Blackfly) Kenya.



Bemisia tabaci (Genn.)

Common name Tobacco Whitefly (Cotton Whitefly)
Family Aleyrodidae
Hosts (main). Cotton, tomato, tobacco, sweet potato and cassava.
(alternative). Many wild and cultivated plants.
Damage Small white scale-like objects on the underside of the leaves. If the plant is shaken, a cloud of tiny moth-like insects flutter out but rapidly resettle.
Pest status A minor pest of cotton in many parts. Attacks are common during the dry seasons, but they disappear rapidly with the onset of rain. A sporadically serious pest of tomato and tobacco. The viruses transmitted are Cassava Mosaic, Cotton Leaf-curl, Tobacco Leaf-curl, and Sweet Potato Virus B.
Life history The egg is about 0.2 mm long and pear-shaped. It stands upright on the leaf, being anchored at the larger end by a tail-like appendage inserted into a stoma. Eggs are white when first laid but later turn brown. They hatch after about seven days.

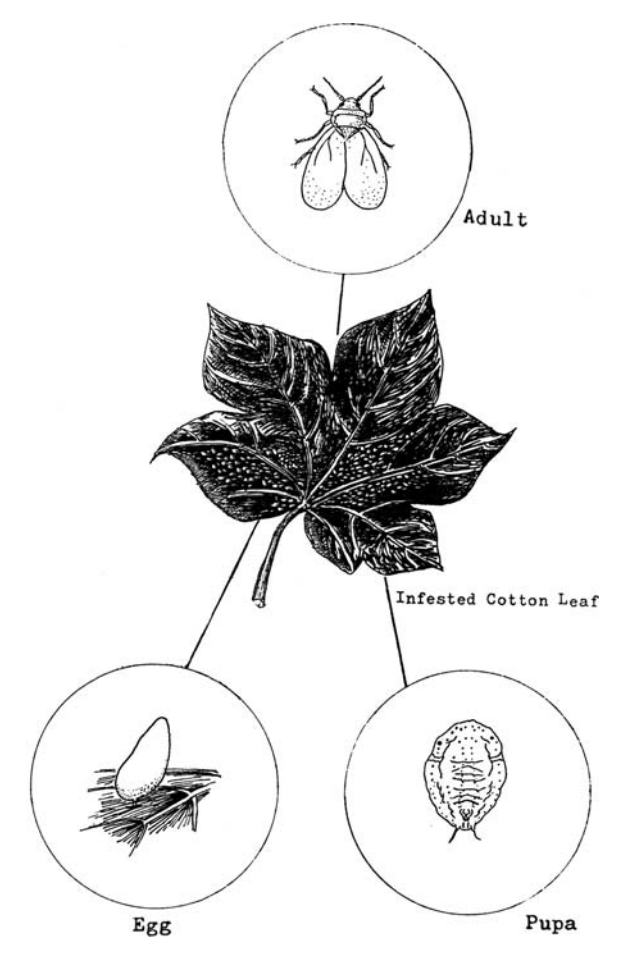


When the nymphs hatch they only move a very short distance before settling down again and starting to feed. Once settled they do not move again. All the nymphal instars are greenish white, oval in outline, scale-like and somewhat spiny.

The last instar (the so-called 'pupa') is about 0.7 mm long and the red eyes of the adult can be seen through its transparent integument. The total nymphal period lasts 2–4 weeks according to temperature.

The adult is minute, about 1 mm long and emerges through a slit in the pupal skin and is covered with a white, waxy bloom. The female may lay 100–160 or more eggs. Adults are long-lived.
Distribution Cosmopolitan occurring as far north as Europe and Japan (CIE map no. A284).
Control Control measures are not usually needed, but if they are then DDT, dimethoate, or pyrethrum, permethrin, fenthion or pirimiphos methyl, as sprays are recommended. The spray should be directed at the undersides of the leaves as far as possible.

Fig. 9.63. Bemisia tabaci (Tobacco/Cotton Whitefly); Kenya.



Dialeurodes citri (Ashm.)

Common name Citrus Whitefly
Family Aleyrodidae
Hosts (main). *Citrus* spp.

(alternative). Coffee (*arabica*), *Gardenia*, *Melia*, and other ornamental trees and shrubs. Polyphagous

Damage The direct damage is mainly the loss of sap caused by the feeding bugs, but the honey-dew excreted often leads to infestation by sooty moulds on both leaves and fruit. Thus damage is often more unsightly than real.

Pest status Not a very serious pest but quite widely occurring and causing unsightly damage.

Life history The eggs are tiny, pale yellow, and laid in batches on the underside of young leaves. Each female lays from 100–150 eggs. The incubation period is 8–24 days.

The young nymphs are active at first, but within a few hours they become firmly attached to the leaf. At the first moult the larvae lose their legs and antennae. There are three nymphal instars and the total nymphal period occupies some 20–30 days.

Pupation usually involves a period of quiescence and consequently may take 14–300 days.

The adults are tiny white bugs with delicate wings, about 1.2 mm long; they only live for about ten days.

The life-cycle may vary from 35 to 330 days. In Florida there are three generations per year.

Distribution S. France, India, Sri Lanka, Pakistan, Italy, USSR, Bangladesh, China, Vietnam, Japan, USA (California, Thailand, S.E. USA), Mexico, Guatemala, and S. America (Brazil, Chile, Peru, Argentina) (CIE map no. A111).

A similar species on *Citrus* with cloudy wings and black eggs is *D. citrifolii* (Morg.) in India, Japan, USA and S. America. Many other species are recorded on a wide range of hosts.

Control Azinphos-methyl, trichlorphon and parathion-methyl will kill both nymphs and adults quite effectively.

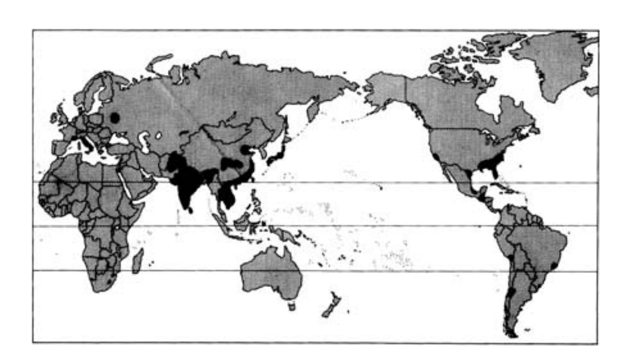
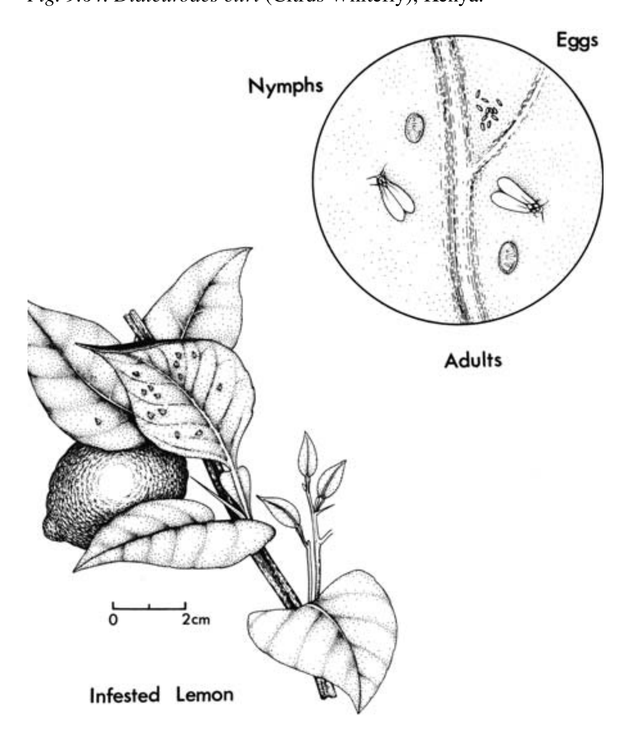


Fig. 9.64. Dialeurodes citri (Citrus Whitefly), Kenya.



Cicadulina mbila (Naudé)
(= *Balclutha mbila* Naudé)

Common name Maize Leafhopper
Family Cicadellidae
Hosts (main) Maize
(alternative). Sugarcane, wheat, millets, and various wild grasses.
Damage Attacked plants show no signs of insect damage for this is very slight at most, but the Streak Disease symptoms are conspicuous yellow streaking against the normal green background of the leaf. Infestation of the young plant may result in its death.
Pest status Actual damage by direct sap sucking is slight, but the 'active' races transmit Maize Streak Virus, which causes extensive damage to maize crops in many parts of E. and Southern Africa.
Life history Eggs are laid in the plant tissue by the female, and the developmental period is 5–6 weeks in E. Africa.

The adult is a tiny leafhopper, 2–3 mm in length, with transparent wings bearing a brown longitudinal stripe. Head, thorax and abdomen are largely yellow with some dark brown markings on the dorsum. The eyes are dark brown. Adults may be found at rest on the upper surface of the young maize leaves forming the terminal cone of the plant. Field densities have been recorded as high as one leafhopper per 20 maize plants, but this is unusually high. The leafhopper exists in two forms (biological races) – an 'active' form capable of virus transmission, and an 'inactive' form which is incapable of transmission, as shown experimentally by Storey (1932, 1961). The active form becomes infective 24 hours after feeding on a diseased plant, and will remain so for up to several months.

Three other closely related species of *Cicadulina* are also capable of transmitting this virus.
Distribution E. & W. Africa, Zimbabwe, and S. Africa, India. The insects are rarely seen but the incidence of Maize Streak Disease is often quite high. (CIEA. 481).
Control The use of resistant varieties of maize is probably the best method of control to be aimed at, and these have been developed at IIT A carried out. Otherwise, having as close a season as possible for maize growing does appear to be effective in reducing leafhopper populations. Sprays of carbaryl, dimethoate or demeton-*S*-methyl can be effective, especially if followed by roguing of diseased plants.

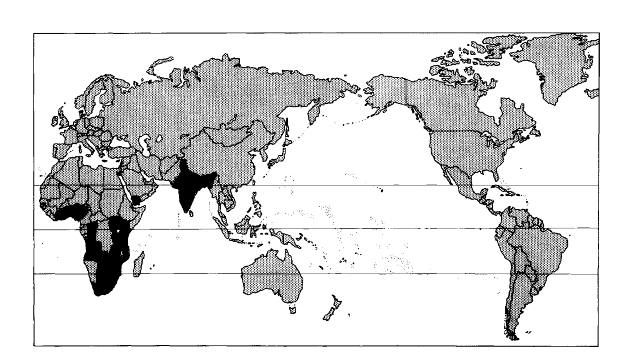
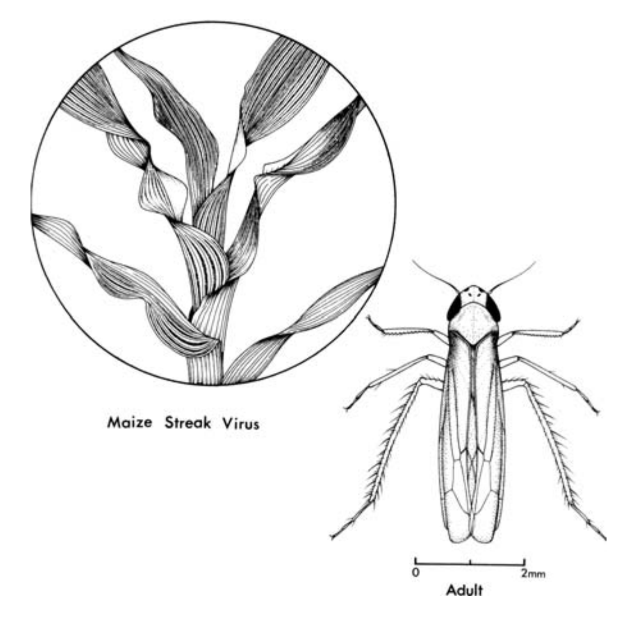


Fig. 9.65. Cicadulina mbila (Maize Leafhopper) Kenya.



Leafhopper pests (Homoptera; Cicadellidae (= Jassidae))

This is a large group of bugs, second in abundance only to the aphids, with some 8500 species, worldwide in distribution with several large cosmopolitan genera, recorded from a wide range of host plants. Most species are restricted in their choice of hosts, but some are polyphagous. Identification of leafhoppers is difficult as the main taxonomic character is the male aedeagus: thus field recognition is only feasible to generic level. As an indication of the abundance of this group in the UK some 37 species have been recorded on top and soft fruit (including hop).

In the tropics breeding is often continuous, with up to 10 generations per year, but in temperate regions the grassland species are generally bivoltine, and the arboreal species univoltine, although up to five generations per year have been recorded in some species. In temperate regions overwintering occurs in any stage, but most frequently as the adult or the egg.

Most are phloem-feeders, but the Typhlocybinae feed from the mesophyll layer of leaves. Crop damage may be direct, caused by feeding, or by transmission of viruses and mycoplasms causing diseases; some have toxic saliva and cause 'hopperburn'.

Eggs, up to 300 per female, are laid under the epidermis of the host plant, singly, or in rows, or clusters, using the short sharp ovipositor.

Dispersal is by young adults in flight, and some species regularly undergo considerable migration, both in Europe and North America and also in the Far East (China and Japan).

Most populations are checked by high levels of natural control through predators and parasites, but some species do regularly require pesticide application.

Control of leafhoppers (jassids)

Many species, especially in the tropics, have now established resistance to a number of the organo-phosphorous insecticides, and so care has to be taken when selecting candidate chemicals. For some species it appears that host-plant breeding for resistance is most successful, as exemplified by *Empoasca* and the 'hairy' strains of cotton.

Pesticides that have been recorded as successful for control of leafhoppers include DDT, azinphos-methyl, carbaryl, dimethoate, demeton-*S*-methyl, endosulfan, formothion, malathion, phorate and oxydemeton-methyl, but the most frequently recommended chemical is still malathion.

Several foliage sprays are generally recommended at 1–2 week intervals, taking care to reach the undersurface of the leaves where the leafhoppers live.

Leafhopper pest species

In addition to the four genera/species mentioned in the text, other temperate leafhoppers of importance as crop pests include:

Amrasca terraereginae (Paoli) – on sunflower in Australia.
Aphrodes spp. – (Strawberry Leafhoppers) Europe and Canada; virus vectors.
Austroasca viridigrisea (Paoli) – (Vegetable Jassid) Australia; on alfalfa, clovers and potato.
Cicadella aurata (L.) – (Potato Leafhopper) UK and Europe.
Cicadella viridis L. – (Green (Hazelnut) Leafhopper) S. Europe, Japan.
Cicadella spectra Dist. – (White Rice Leafhopper) Japan.
Dalbulus maidis D. & W. – (Corn Leafhopper) (on maize); USA, C. and S. America.
Edwardsiana rosae (L.) – (Rose Leafhopper) Europe, Japan, USA; polyphagous.
Erythroneura mori Mats. – (Blood Spot Leafhopper) China and Japan; on persimmon and mulberry.
Erythroneura spp. – (Striped Apple Leafhoppers) five species recorded on apple in the USA.
Erythroneura spp. – (Grape Leafhoppers) China, Canada, USA.
Eurypteryx stellulata Burm. – (Cherry Leafhopper) Europe.
Euscelis obsoletus – (Apple Leafhopper) Europe.
Euscelis spp. – on strawberry; Europe.
Graminella spp. – (Cereal (Grass) Leafhoppers) cereals and grasses; USA.
Ledra aurita (L.) – on hazelnut; S. Europe (not UK).
Macropsis trimaculata (Fitch) – on plum; USA.
Macropsis spp. – on *Rubus* spp.; cause stunt disease; UK.
Macrosteles fascifrons (Stål) – (Six-spotted Leafhopper) on lettuce, celery and carrot it is a serious pest in Canada and USA as a virus vector; also feeds on potato, oats, barley, flax, sunflower, rye, parsnip, strawberry and clovers, and transmits viruses on these crops. Regularly a migrant species into Canada from the USA.
Nephotettix spp. – (Green Leafhoppers) on rice and grasses; Africa and Asia; most species tropical in distribution (CIE maps nos. A.286 and 287).
Zygina pallidifrons (J.Ed.) – (Glasshouse Leafhopper) on rose, tomato, cucurbits and other glasshouse crops; Europe.
Zygina spp. – five species recorded on fruit trees in the UK, and several in Japan.

Empoasca spp.
fascialis (Jacobi)
lybica (De Berg)

Common name Cotton Jassids
Family Cicadellidae (= Jassidae)
Hosts (main) Cotton

(alternative). Various legumes, wild Malvaceae, groundnut, castor and many other crops.

Damage The edges of leaves are down-curled and turn first yellow and then red. In severe attacks leaves may dry up and be shed. On the undersides of leaves numerous pale green bugs can be found which may move rapidly sideways when disturbed.

Pest status Most of the time only a minor pest of cotton, due to the use of resistant varieties, but locally severe attacks occur from time to time.

Life history The eggs are greenish, banana-shaped and about 0.8 mm long. They are embedded in one of the large leaf veins or in the leaf stalks. Hatching occurs after about 6–10 days.

There are five nymphal instars; the full-grown nymphs are yellowish-green, frog-like and about 2 mm long. Nymphs are found on the underside of large leaves during the daytime. The nymphal period lasts 14–18 days.

Adults are pale green, narrow-bodied, wedge-shaped bugs about 2.5 mm in length. The wings are semi-transparent and extend beyond the end of the body. The adult hops and flies very readily if disturbed, or, like the nymph, runs quickly sideways. Adult females may live 2–3 weeks or longer, and lay about 60 eggs.

Distribution *E. fascialis* is recorded from 24 countries in tropical Africa (CIE map no. A250).

E. lybica is found in Spain, Israel, Saudi Arabia, Aden, Egypt, Ethiopia, E. Africa, Sudan, Tunisia, Libya, Mauritius, Morocco, Somalia, and S. Africa (CIE map no. A223).

Control Cotton varieties with suitably hairy leaves are resistant to jassid attack. If control measures are required then the recommendations are to spray with DDT, endosulfan, dimethoate, formothion or carbaryl, etc.

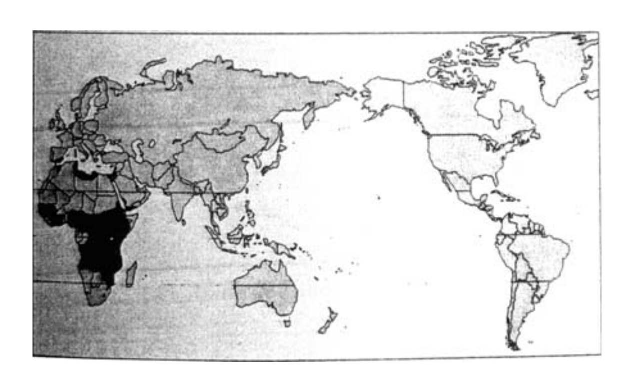
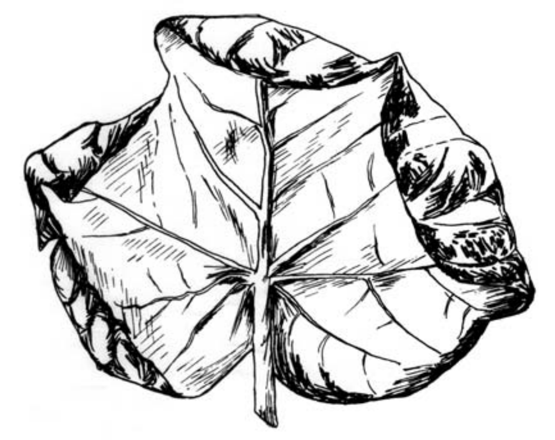


Fig. 9.66. Empoasca sp. on cotton leaf; Kenya.

Empoasca sp.

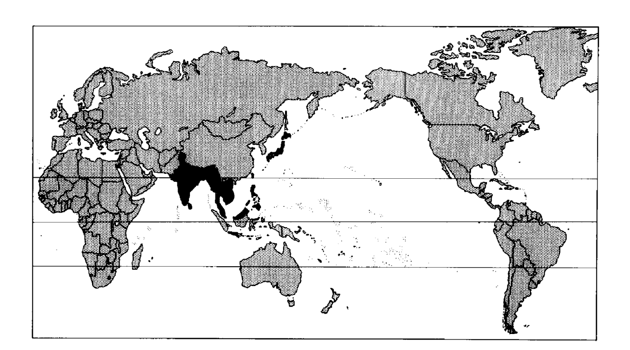
Nymph and Adult



Recilia dorsalis (Mot.)

(= *Inazuma dorsalis* (Mot.))

Common name Zig-zag Winged Rice Leafhopper
Family Cicadellidae
Hosts (main) Rice
(alternative). Sugarcane, wheat, barley.
Damage Direct damage is done by the removal of sap, and indirect damage by being the vector for various viruses.
Pest status One of the more important leafhoppers which are pests of rice. This species transmits Orange Leaf, and Rice Dwarf viruses.



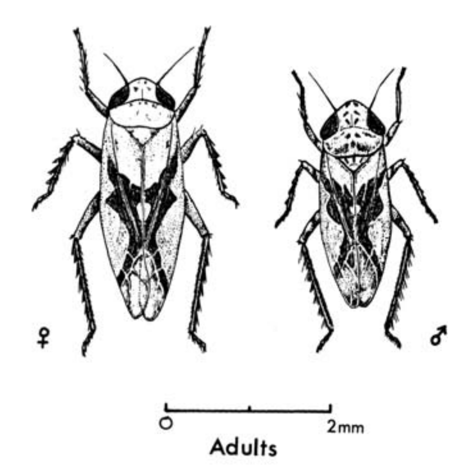
Life history Eggs are laid in rows within the leaf sheath, and hatch in 7–9 days.

There are five nymphal instars, which last about 16–18 days. The nymphs are yellow-brown.

The adults are 3.5–4.0 mm long, with white forewings with pale brown bands forming the shape of a 'W' giving the wing a zig-zagged pattern.
Distribution India, Sri Lanka, Malaysia, Philippines, Java, Thailand, China, Taiwan, and Japan.
Control As with *Nephotettix*, the use of light traps and weed removal will reduce leafhopper populations.

Carbaryl, malathion, azinphos-methyl and endosulfan, sprayed at weekly intervals, are successful insecticides.

Fig. 9.67. Recilia dorsalis ♀ and ♂.



Nephotettix spp. (8)

Common name Green Rice Leafhoppers
Family Cicadellidae
Hosts (main). Rice
(alternative). *Panicum* spp., *Cyperus* spp., *Poa* spp., and other grasses.
Damage Nymphs and adults cause direct damage by sucking the sap from young leaves, and they also transmit several plant viruses.
Pest status A sporadically serious pest in many Asiatic rice-growing areas when populations build up rapidly. Small numbers are of little consequence as they do negligible damage. This and two other closely related species, *N. cincticeps* and *N. impicticeps*, are vectors of the viruses causing Yellow Dwarf, Transitory Yellowing, and other viruses.
Life history Eggs are laid in the leaf sheaths, where they hatch in about six days.

Nymphs have a varied colour pattern on the motum. There are five instars before they become adult, after 16–18 days.

Adults are 3.2–5.3 mm long, green, with black spots on wings, and black wing tips.
Distribution India, Pakistan, Burma, S.E. Asia, Japan, Philippines, S. China, Indonesia, Papua New Guinea, Australia, and West Irian (CIE map no. A286 & A.287).
Control Removal of weeds from around the crop fields can lower the pest population, for many of these plants are alternative hosts for the leafhoppers. The adults are greatly attracted to light, and populations can be depleted by the use of light traps.

Suggested insecticides are carbaryl, malathion, azinphos-methyl, and endosulfan, to be sprayed at weekly intervals. Or diazinon as granules to be applied to the irrigation water.

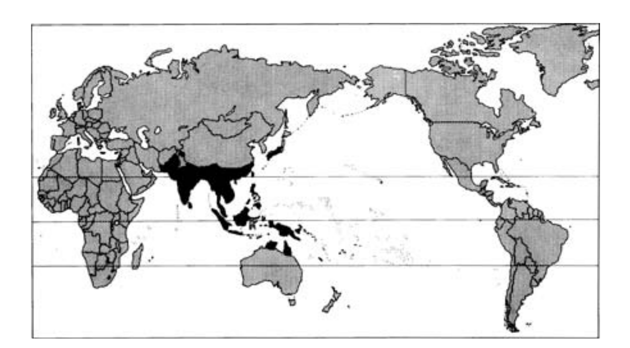
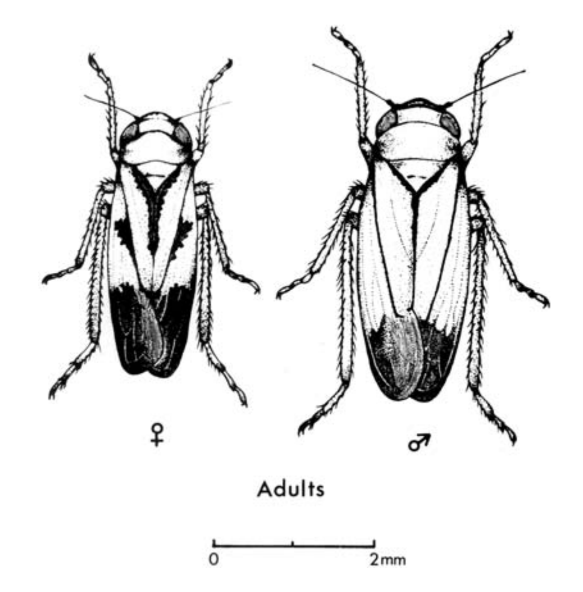


Fig. 9.68. Green Rice Leafhopper (*Nephotettix* apicalis) ♂ and ♀ S. China.



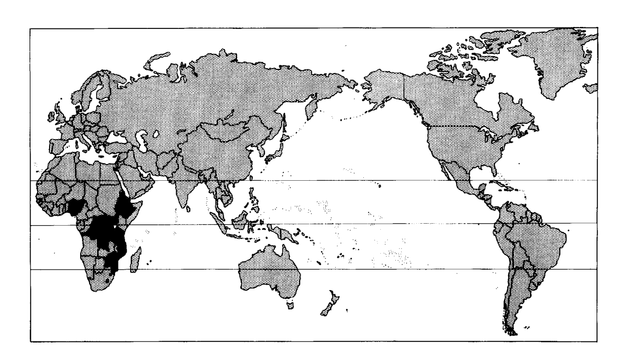
Hilda patruelis Stål

Common name Groundnut Hopper
Family Tettigometridae
Hosts (main) Groundnut

(alternative). Various legumes, including beans, sann hemp, other *Crotalaria* spp., marigold, sunflower, cashew, Fig. *Althaea*, *Citrus*, etc.

Damage The adults and nymphs suck sap from the stem, pegs and pods usually just below ground level. Severe damage (wilting and collapse) may be done by this bug when it occurs in large numbers. The first sign of infestation is the presence of black ants in association with the *Hilda* bugs. The ants construct chambers in the soil around the bugs and protect them from enemies. In return the bugs provide honey-dew as food for the ants.

Pest status This pest is not often important, but may be locally serious. It does not transmit Rosette Virus.



Life history The eggs are small, white, and elongate, and laid in batches (10–40) on the stem at or below ground level, and on the pegs and pods, in leafaxilson *Citrus* and *Ficus*.

The nymphs look like small versions of the adults but without wings.

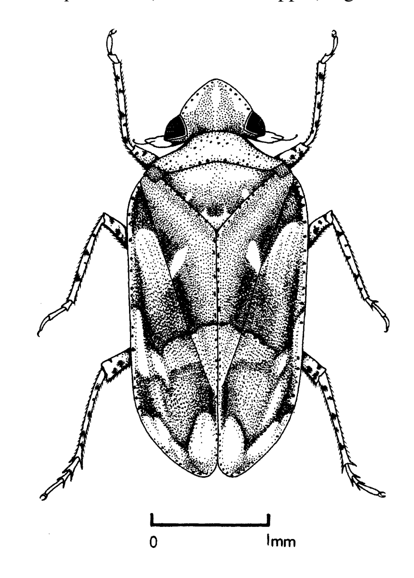
The adult is a small stout bug 4–5 mm long, with greenish-brown markings and three lateral white patches on each forewing. Some specimens are completely green. Colour variation is recorded.

In Zimbabwe it is reported that one generation took about six weeks in the summer. Reproduction proceeds slowly on any overwintering plants.

Distribution Africa; including Nigeria, Zaïre, Uganda, Ethiopia, Tanzania, Zimbabwe, and Mozambique.

Control Chemical treatment is not often required, but if it is then the soil may be treated with dieldrin before planting, which may kill the *Hilda* bugs and will certainly kill the ants which encourage the bugs.

Fig. 9.69. Hilda patruelis (Groundnut Hopper) Uganda.



Nilaparvata lugens (Stål)

Common name Brown Rice Planthopper (BPH)
Family Delphacidae
Hosts (main) Cultivated rice.
(alternative). Wild species of *Oryza* only.
Damage Heavy infestations produce symptoms of 'hop-per-burn' – leaves dry and brown after insect feeding (toxic saliva), and patches of 'burned' plants are often lodged. This insect is a vector of Grassy Stunt Virus Disease. The rice plant is most sensitive to attack at the age of 26–39 days.
Pest status Ten years ago this was a minor pest of rice in parts of S.E. Asia, but its status has changed dramatically to become one of the most serious rice pests in many parts of S.E. Asia, eastern India and Japan. The reasons for this change in pest status are several, some new high-yielding rice varieties have less resistance to pest attack, some insecticides have had serious adverse effects on the natural enemies, the pest has developed resistance very quickly to many of the regularly used pesticides, and increased irrigation combined with poor drainage has resulted in much more wild rice and volunteer rice available as reservoir hosts.
Life history Small white eggs are laid in batches inside the leaf sheath and on the leaf midrib; hatching requires 5–9 days. Each female lays about 200 eggs. Nymphs are brown and reach about 3 mm in length after 12–18 days, whereupon they moult into adults. Adults may be fully winged or brach-ypterous (short-winged); males tend to be smaller in size than females, some 2.5 mm as opposed to 3.0 mm. The adults live for about three weeks. There are four or more generations per year.

In Japan this pest arrives annually from the China mainland, during the period mid-June to mid-July, and once on the local rice crops populations build up rapidly, there being four generations during the summer in southern Japan. However, the winter is too cold and the insects do not survive.

This pest is also unusual in that it develops biotypes in relation to insecticide resistance, which cannot be identified morphologically.
Distribution From eastern India through S.E. Asia to Papua New Guinea and Australia (Queensland), to the Philippines, and to China. It occurs annually in Japan as a migrant from E. China (CIE map no. A199).
Control Resistant varieties of rice are obtainable from IRRI, and various types of cultural control can be practised to reduce infestation levels. In some areas natural predation (especially by spiders and bugs) and parasitism is important. Certain pesticides should be avoided – for example, diazinon and quinalphos invariably causes a pest resurgence in S.E. Asia. Advice for insecticidal control should be sought locally. Sprays should be directed at the base of the plants.

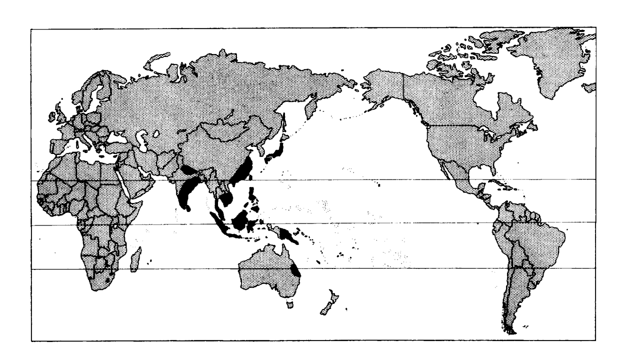
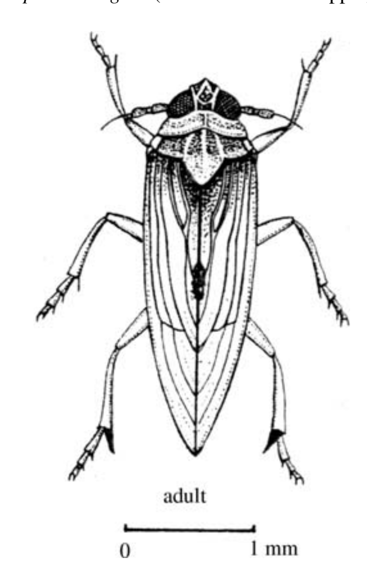


Fig. 9.70. Nilaparvata lugens (Brown Rice Planthopper) Malaysia.



Perkinsiella saccharicida (Ckll.)

Common name Sugarcane Planthopper
Family Delphacidae
Hosts (main) Sugarcane
(alternative). A few species of grasses.
Damage The nymphs and adults feed on the leaves, sucking the sap. Damage also includes laceration of tissue by the ovipositor with subsequent reddening, and desiccation of the leaves. When the insects are numerous the honey-dew excreted covers the leaves and sooty moulds are common.
Pest status A pest of some importance on sugarcane; occasionally severe outbreaks have been recorded in Hawaii. It is a vector of Fiji Disease.
Life history Oviposition takes place by night; each female lives for 1–2 months and will lay about 300 eggs. The eggs are laid in the midrib of the leaf, low down on the upper surface, but they may be placed in the leaf sheath, leaf blade or shoot. The egg is elongate, cylindrical, and slightly curved, about 1.0 by 0.35 mm. From 1–12 eggs may be laid in a single incision; the upper ends, which have a dome-like cap, project slightly above the leaf surface. Incubation takes 14–40 days.

Each of the five nymphal instars lasts 4–9 days.

Both males and females may be brachypterous or macropterous. The adult bugs regularly migrate from crop to crop. The adults rest in the leaf funnels and other places of shelter during the day.

The whole life-cycle takes about 48–56 days; there are five or six generations per year.
Distribution S. Africa, Madagascar, Malaya, Thailand, S. China, Sarawak, Java, Australia (Queensland), Hawaii, and S. America (Ecuador and Peru) (CIE map no. A150).

There are 22 species of *Perkinsiella*, but not all are recorded from sugarcane.
Control Both systemic and contact insecticides have been used to control Fiji Disease (e.g. BHC, dimethoate, dicrotophos, parathion, and dimefox).

In Hawaii the egg predator *Tytthus mundulus* was introduced and in conjunction with other natural enemies has kept the pest under virtually complete natural control since 1923. This is one of the classic examples of very successful biological control.

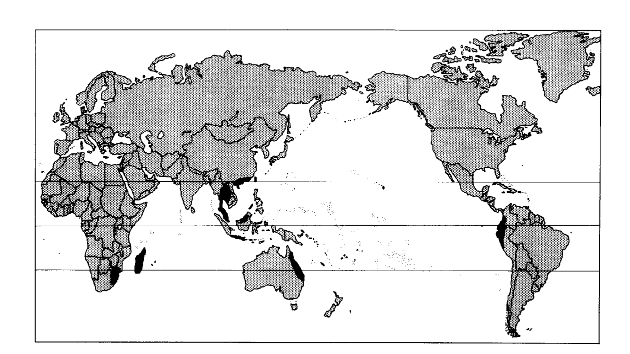
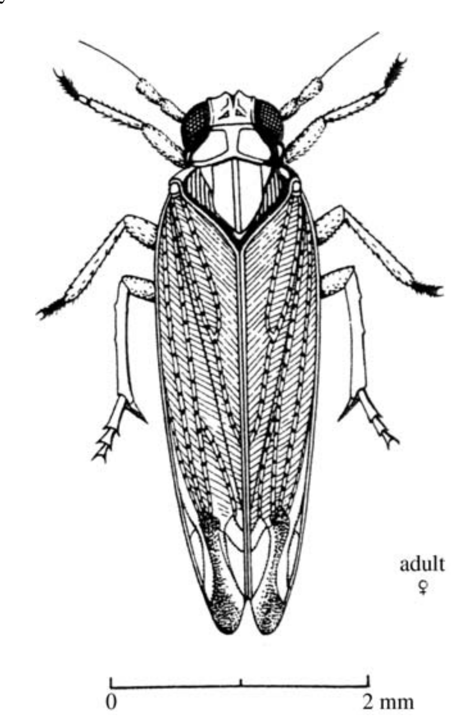


Fig. 9.71. Perkinsiella saccharicida (Sugarcane Planthopper); Malaya.



Sogatella furcifera (Horv.)

Common name White-backed Planthopper
Family Delphacidae
Hosts (main) Rice
(alternative). Various species of grasses, maize and millet.
Damage This species is generally found during the early growth stages of the rice crop and population build-up can be rapid. Damage is direct as a result of sap loss by the rice plants, tillering may be delayed, grain formation reduced, or the plant may even be killed. Rice Yellows cause a reddish-yellowing of the foliage (hopper-burn) and the plants become stunted.
Pest status A pest of sporadic importance on rice, but it has been recorded as a virus vector of Rice Yellows and Stunt Disease which makes it a far more serious pest.
Life history The eggs are laid in masses in the leaf sheath, each with a long narrow egg-cap. Hatching takes about 3–6 days.

The nymphs are pale brown, and range in size from 0.6 mm when young to 2.0 mm when fully developed. Nymphal development takes 11–12 days.

The adult is about 3–4 mm long, and is distinguished by the absence of a median transverse ridge on the vertex. The vertex is characteristic in giving the insect a long narrow face. The forewings are hyaline with dark veins, and a conspicuous dark spot in the middle of the posterior edge. The pronotum is pale yellow, and the body black. The adults live for about 18–30 days, the females living a little while longer than the males.
Distribution Bangladesh, India, Sri Lanka, S.E. Asia, Malaysia, Philippines, Indonesia, China, Korea, Japan, N. Australia, and the Pacific islands (CIE map no. A200).
Control Control is as for other leafhoppers (e.g. *Nephotettix*), but the other insecticides found to be effective are as follows: dimethoate, DDT, dieldrin, aldrin, endrin, phosphamidon, disulfoton, and monocrotophos.

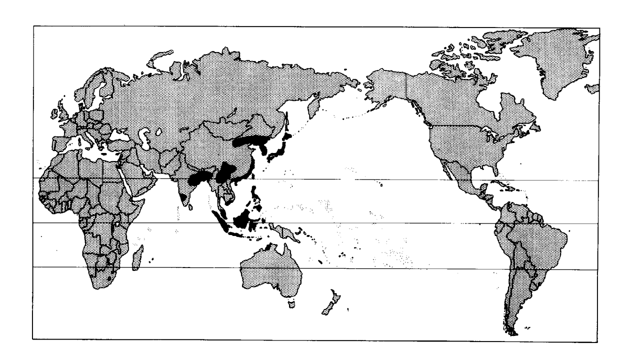
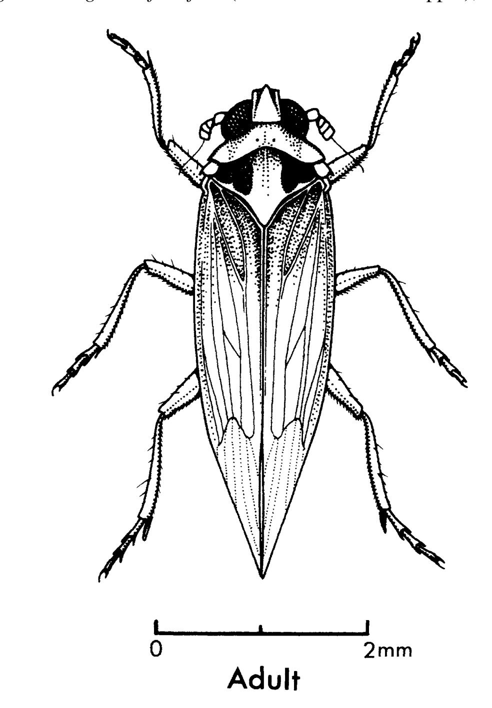


Fig. 9.72. Sogatella furcifera (White-backed Planthopper); Malaya.



Pyrilla perpusilla Wlk.

Common Name Indian Sugarcane Leafhopper
Family Lophopidae
Hosts (main) Sugarcane
(alternative) Millets, wheat, maize and other species of Gramineae, and some dicotyledons.
Damage Damage consists mainly of sap removal from the plant by the feeding of the nymphs and adults.
Pest Status Not a serious pest, but various lophopids are of wide occurrence on crops and plants in the tropics.
Life History Eggs are white, ovoid, 1.0 × 0.5 mm, and are laid almost touching on the leaf in two to four irregular rows, covered with a white waxy secretion. Each batch contains 30–50 eggs. Incubation takes 6–18 days.

After 3–4 hours the nymphs disperse; feeding is most frequent on the underside of the leaves. Honeydew is excreted in some quantities, and many ants are usuall in attendance, abd sooty moulds are common. There are five nymphal instars, taking a total of 5–20 weeks for completion, althought eight is more usual. The adults are not strong fliers, but they jump readily. They are 7–8 mm long, pale brown with conspicuous veins in the forewings and scattered tiny dark spots. The complete life-cycle normally takes from 40–45 days, but in winter developmnt is more prolonged. There are usually 3–5 generations per year.
Distribution Pakistan, India, Sri Lanka, Afghanistan, Burma and Thailand (CIE amp no. A 151).
There are two species of *Pyrilla* found in India and Sri Lanka, but 15 subspecies are recognized.
Control Control is seldom required.

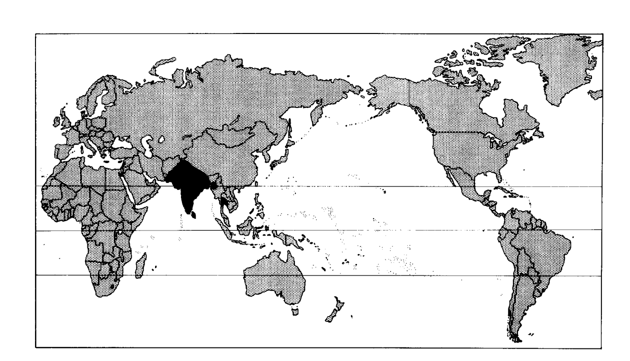
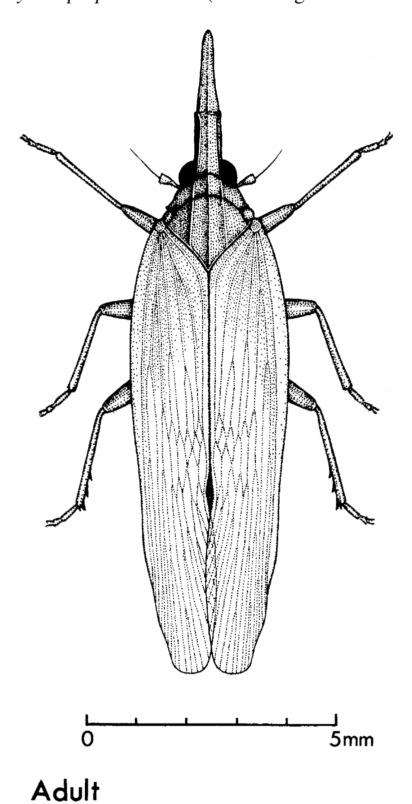


Fig. 9.73. Pyrilla perpusilla adult (Indian Sugarcane Leafhopper).



Pyrops candelaria (L.)

Common name Litchi Lantern Bug
Family Fulgoridae
Hosts (main) Litchi and longan.
(alternative). Occasionally seen on *Acacia confusa*.
Damage Some direct damage by sap-sucking, but most fulgorids do not act as virus vectors and neither do they have toxic saliva.
Pest status Generally only a minor pest, but common and very conspicuous.
Life history Few details are available about the life history of this insect. Eggs are deposited into the host plant tissues via the ovipositor of the female, and nymphs are to be found developing alongside adult: on the trees.

The adults are very distinctive insects, with a mottled green coloration, long anterior 'snout' and hindwings coloured bright yellow with a terminal black band; in total body length from 40–50 mm. The adults live for several weeks, and are usually to be found sitting upright on the tree-trunk, but sometimes up in the foliage. There is usually only one generation per year in S. China.
Distribution To date, only recorded from S. China. There are several closely related species with different coloration in Malaysia and Borneo.
Control This insect is more of academic interest than economic, and normally does not require control measures. It is sometimes parasitized by a strange little moth larva called *Epipyrops*.

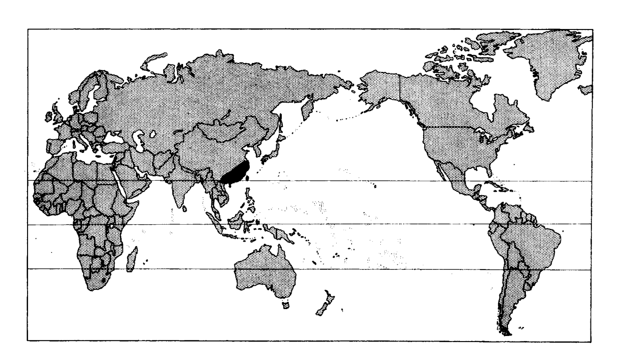
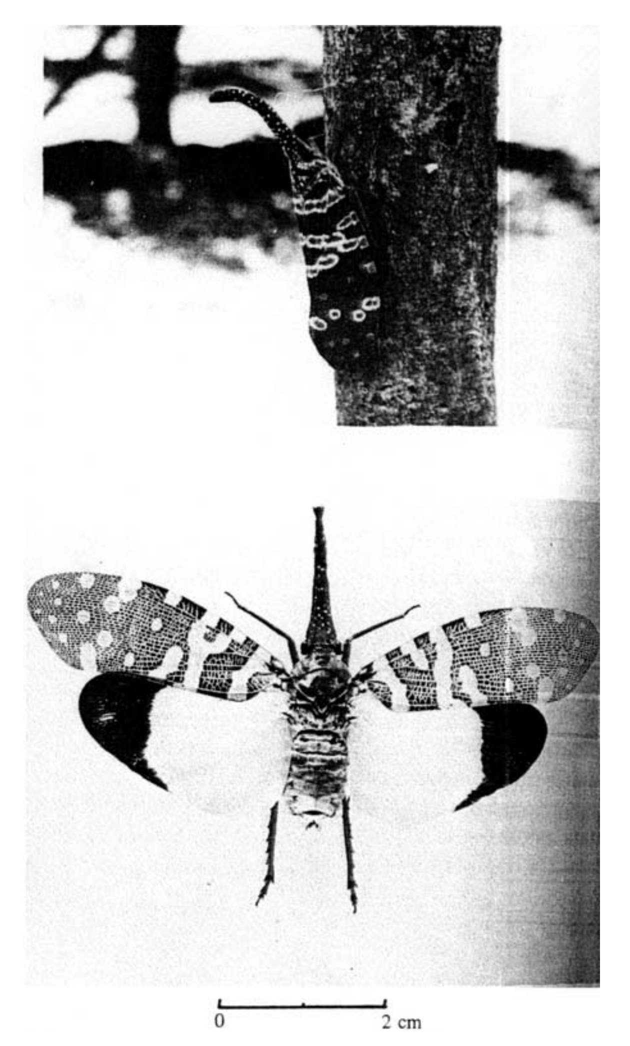


Fig. 9.74. Pyrops candelaria adults, resting on Litchi tree trunk, S. China.



Colobesthes falcata Guér.

Common name Cocoa Moth Bug
Family Flattidae
Hosts (main) Cocoa

(alternative). Some other forest trees, usually Sterculiaceae as saplings.

Damage Some damage is done directly by loss of plant sap, but when they feed on the developing pods their feeding punctures may be used as sites for invasion by pathogenic fungi and bacteria. The young larvae produce quite copious wax on the pods which has a nuisance value. The bugs are gregarious in habits and so their numbers are sometimes sufficiently large that their feeding punctures on the pods are quite damaging. Often the adult bugs seem to prefer to sit on the pod peduncles.

Pest status Usually only a minor, but interesting, pest of cocoa.

Life history Eggs are laid in cracks in the leaf midrib, or in twigs, in a single row of up to 100, and are covered with white waxy filaments. Young nymphs are also covered with waxy filaments, which often form long curling threads. The young nymphs tend to stay on flush leaves and shoot tips, but the older ones are usually found on the bronze leaves and young pods.

The adults are white, moth-like bugs about 15–20 mm in length, with a distinctive shape, and short legs. When disturbed they rise in a group rather like white moths.

Distribution Indonesia and Malaysia.

The closely related species *Lawana candida* (F.) and *Pulastya discolorata* are also to be found on cocoa, kapok, coffee and *Sterculia* in the region from S. China down to Indonesia and Malaysia.

Control Normally not required; probably the nymphs are difficult to kill with contact insecticides because of the copious wax.

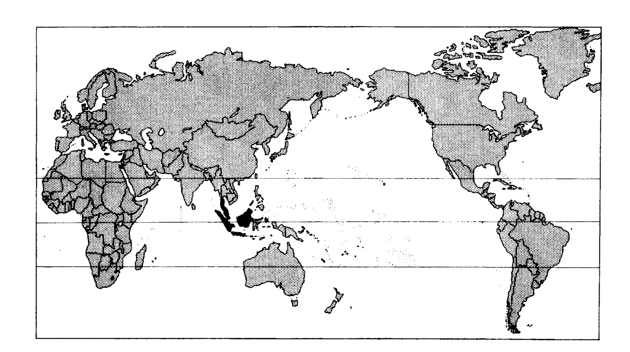
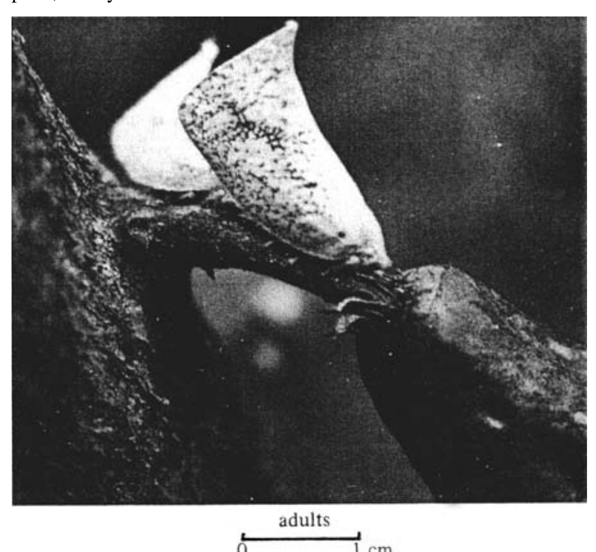


Fig. 9.75. Colobesthes falcata (Cocoa Moth Bug) resting on Cocoa pods; Malaya.



Ricania spp.

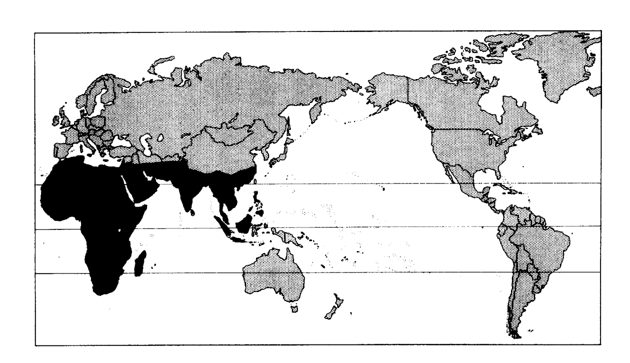
Common name Ricaniid Planthoppers
Family Ricaniidae
Hosts Various plants including palms, *Citrus*, cocoa, wild sugarcane, according to the species of insect.
Damage Usually slight, but the insects are common in tropical regions, and often found on cultivated plants.
Pest status Usually insignificant.
Life history Eggs are laid in rows along the leaf midrib, from which they protrude and are quite visible on careful examination Egg development takes from 6–9 days. The nymphs resemble psyllid nymphs in appearance and bear long waxy filaments from the end of the body; they tend to be gregarious in nature. When alarmed they can jump.

Adults have large expanded forewings which are held out sideways at rest, and give the insects a distinctive appearance; body length is about 8–10 mm. As with other Fulgoroidea the antennae are tiny and inconspicuous.
Distribution The genus is found throughout tropical Africa and Asia, up to S. China, as a number of different species.

R. speculum Wlk. is blackish with white spots and found from Malaysia to China, and is a regular minor pest of oil palm.

R. cervina Mel. is greenish in colour and a regular minor pest on cocoa in W. Africa. A green species, to date only identified as *Ricania* sp. is of regular occurrence on *Citrus* in S. China.

Another unidentified species of *Ricania* is brown with pale bands and to be found in large numbers on various wild Gramineae in S. China.
Control Not usually required.





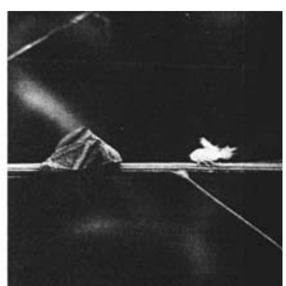
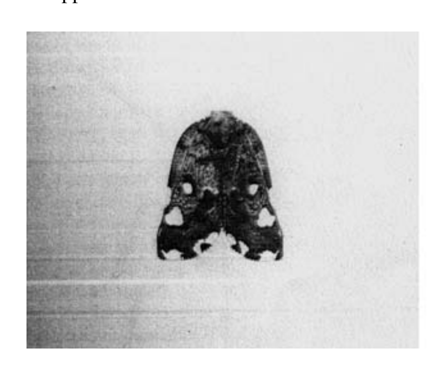


Fig. 9.76. Ricania sp. on Miscanthus grass in S. China.



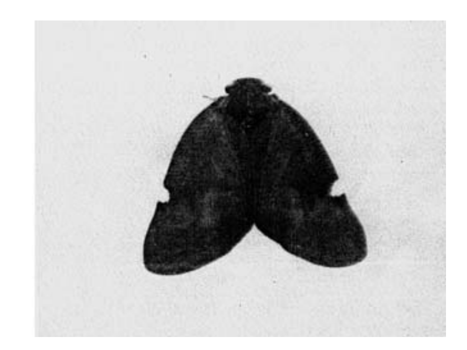


Fig. 9.77. Ricania spp. from S.E. Asia.

Aphis craccivora Koch
(= *A. leguminosae* Th.)
(= *A. laburni* Kalt.)

Common name Groundnut Aphid
Family Aphididae
Hosts (main). Groundnut, other Leguminosae,
(alternative). Polyphagous on many plants.
Damage Some wilting results from the sap-sucking by the aphids in hot weather, but the most serious damage is the transmission of Groundnut Rosette Virus. The leaves of the infected plant typically assume a mottled appearance with either chlorotic or dark green spots according to the form of virus, and the plant develops a stunted habit.
Pest status In itself, this is not a serious pest, but it is very important as the vector of Groundnut Rosette Virus and some 13 other viruses. The virus is brought into the crop by winged adult aphids, and is then transmitted within the crop by both wingless and further winged forms.
Life history Adults are black or dark brown, variable in size, being from 1.5 to 2 mm long; siphunculi and cauda black; antennae are about two-thirds as long as the body.

Nymphs are wingless, dark, and fairly rounded in body shape, and they appear in the crop soon after germination, the adults usually have over-wintered (or spent the dry season) on nearby leguminous plants.

The Rosette Virus is transmitted in a persistent manner. The acquisition period is usually more than four hours and the virus persists for more than ten days, and through the moult. The virus is transmitted by all stages of the insect but the nymphs are more effective than the apterae.
Distribution Virtually cosmopolitan, but records are rather sparse in some areas; however, distribution is expected to be continuous (CIE map no. A99).
Control Cultural control can be effective through early planting, and close spacing.

For chemical control menazon as a seed dressing, or dimethoate as weekly sprays, or menazon as fortnightly sprays are recommended. The seed dressing should give protection for about five weeks.

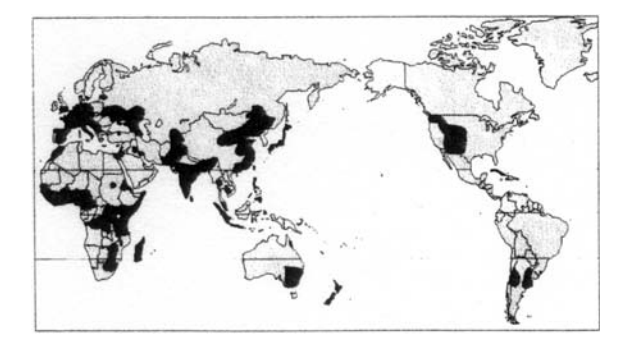
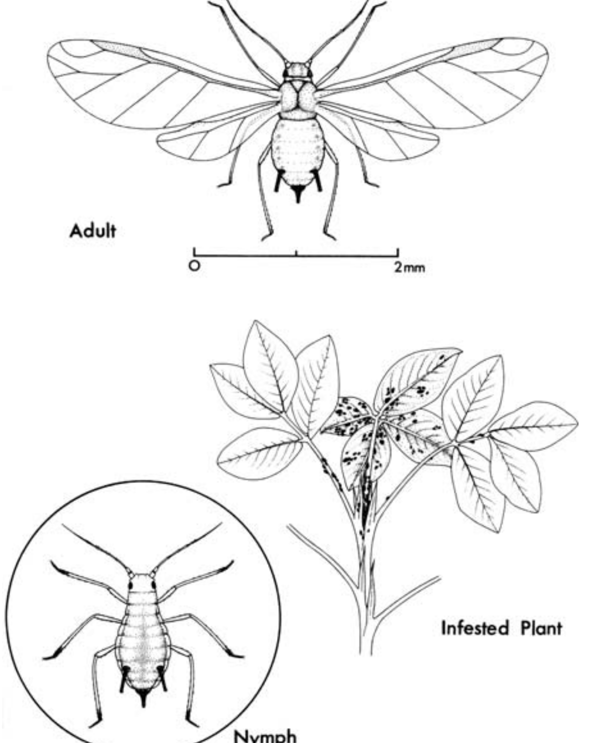


Fig. 9.78. Aphis craccivora (Groundnut Aphid); Kenya.



Aphid pests (Homoptera; Aphididae)

This is not the largest family of insects, there being about 3500 species described, but it is certainly one of the most abundant groups, and is clearly the most abundant of the Homoptera and characteristic of the northern temperate regions. It is found equally well represented on woody and herbaceous plants, and many species alternate between woody hosts in the winter and herbaceous plants in the summer. Almost every species of higher plant is attacked by at least one species of aphid. Some aphids are quite host-specific and will only feed on one genus of plants; at the other extreme are polyphagous species recorded from dozens of different families! On some of the more important crops there may be found up to a dozen different species of aphids, at different levels of abundance. Identification in the field is difficult for many species, as generally the taxonomic characters are esoteric and microscopic; but some species may be recognized on sight (using a hand lens); with practice, by a combination of colour, size, host plant (and location) and obvious anatomical characters. Many distribution and host records made in the past are now discounted owing to misidentification and to confusion over names. Generally most crops can be expected to act as host for half-a-dozen or even more aphid species, and so field infestations have to be identified with extreme care. In the UK in 1977 two keys were published for the field identification of aphids on field crops (brassicas, potato and sugar beet) and cereals, by MAFF, and these do permit field identifications with some measure of certainty; other such keys are clearly required for all the major crops.

The life-cycles are spectacular in that they involve polymorphism, parthenogenesis, viviparity, and alternation of generations on different host plants. A typical life-cycle would be represented as follows. The winter is spent as eggs laid the previous autumn by sexual females. In the spring the eggs hatch into apterous parthenogenetic viviparous females; these produce a new generation of similar forms, but with a few winged females. Several similar generations are produced during the summer and winged viviparous females become more common. By mid-summer the winged females are very abundant and swarms are produced for dispersal purposes in numbers sufficient to darken the sky! Towards the end of summer the progeny of the dispersed females that landed on appropriate host plants, together with those of the apterous forms which remained on the original plant, give rise to sexual females and to males. The new adults mate and the oviparous females lay eggs which will overwinter on the food plant. Many species are truly migratory and the winter is spent on woody trees and the summer on herbaceous plants.

In the tropics the situation is simpler in that males are rare or totally absent and alternation of hosts not practised.

A few species make galls on the host plant, but these are mostly members of the closely related family Pemphigidae (sometimes regarded as a subfamily of Aphididae).

Some of the polyphagous and cosmopolitan ‘species’ such as *Myzus persicae* occur as distinct physiological races with different host preferences, but no observable differences in anatomy or morphology.

Most aphids are phloem feeders but some use the xylem system of the host plants also. Honey-dew excretion is general, but some species are more prolific in their production. Aphid saliva does in some cases seem to be toxic and direct feeding damage usually consists of leaf-curling and wilting in severe attacks, with some growth stunting but young soft shoots may be killed. Many species are virus vectors and thus major crop pests; for example *Myzus persicae* is recorded to transmit more than 100 virus diseases of plants in about 30 different families including most of the more important (non-cereal) crops.

Aphid populations are preyed upon very heavily by many insect predators, especially Coccinellidae and Syrphidae, and many parasitic Hymenoptera, and all management programmes should endeavour not to upset the natural control usually present.

Aphid pest species

In addition to the species already specifically mentioned, the following are pests in warmer countries.

Rhopalosiphum rufiabdominalis (Sasaki) – (Rice Root Aphid) on rice, other cereals, sugarcane, *Prunus*, potato; cosmopolitan but more tropical (CIE map no. A.289).
Rhopalosiphum padi (L.) – (Oat–Bird Cherry Aphid) primary host is bird cherry, secondary mostly Gramineae, wheat, oats, rice, other cereals, also apple, virus vector; cosmopolitan but more temperate (CIE map no. A.288).

Sitobion avenae (F.) – (Grain Aphid (many synonyms)) on wheat, barley, oats, and other Gramineae, virus vector; Europe, USA.

Sitobion fragariae (Wlk.) – (Blackberry—Cereal Aphid) overwinters on *Rubus* and migrates on to cereals and grasses in summer; Europe.

Therioaphis maculata (Buckton) – (Spotted Alfalfa Aphid) on alfalfa and some other forage legumes; Mediterranean Region, Middle East, India, and USA (CIE map no. A.126).

Control of aphids

Direct damage to crop plants by feeding aphids is mainly the removal of nutrients and water from the tissues which is insignificant in small infestations but causes loss of vigour and wilting if populations are large. It does appear that some species have toxic substances in the saliva and these species cause foliage distortion and stunting of plants, and young shoots of plum, apple, etc., may be killed. Young plants are generally more susceptible to damage, and growth may be seriously impaired, whereas older or mature plants tolerate quite large aphid infestations without showing any deleterious effects. Grain aphids on young cereal ears may cause blindness or shrunken kernels; on nearly ripe grain the effect is negligible. Foliage

discoloration is quite common, but the most spectacular is that caused on apple leaves by Rosy Leaf-curling Aphid. Honey-dew production may be quite serious, partly by allowing sooty moulds to develop, and in cereal ears the stickiness makes harvesting difficult.

Aphids are vectors of most plant viruses in temperate regions and thus their indirect damage is often very serious. Since only one or two infested aphids may innoculate a crop, prevention of diseases by insecticide application is extremely difficult; plant breeding for resistance is the most successful method of combatting virus diseases.

In a few cases the destruction of alternative host plants has been a method of controlling an aphid species, but this is a drastic procedure and seldom likely to be successful. Sometimes the spraying of alternative hosts with insecticides has been profitable, and the monitoring of aphid populations on the alternative hosts has been used to predict both size of populations and timing of immigration on to field crops (Way *et al*, 1981).

It is difficult to protect a field crop from aphid infestation, but is quite feasible to protect seed beds under a gauze shelter for the crops that are planted out as young seedlings (e.g. brassicas, tobacco, etc.). Experiments have shown that surrounding seed beds with reflective strips, or blue-coloured fabric, has a protective action in that this colour deters aphids from settling (alternatively they are attracted to yellow).

Natural control by predators and parasites is very important, particularly so on orchard crops and perennial plants, and so pesticide use must be very judicious. It has been recorded many times that careless use of some insecticides actually exacerbated aphid pest situations on some crops. This is one of the reasons why granular formulations of aphicides are popular.

Economic thresholds have been worked out for a number of important aphid pests in the UK, and include the following:

Apple: *Rhopalosiphum insertum* – if 50% trusses have aphids at bud-burst.
Dysaphis plantaginea – any aphids found at bud-burst.
(Then spray an aphicide before flowering.)

Wheat: *Sitobion avenae* – if five aphids per ear found at start of flowering, and weather conditions fine.
Metopolophium dirhodum – 30+ aphids found per flag leaf.

Other thresholds are known; for further details the local ADAS (MAFF) staff should be consulted.

Many aphid infestations are attended by ants whose presence clearly deters many of the natural enemies; natural control can be greatly enhanced by either sticky bands or spray-banding the host tree trunk to deny access to the ants; often such a measure is all that is required to control an aphid population in the field.

Being small and soft-bodied, aphids are very sensitive to environmental conditions, and most populations are severely depleted by a spell of bad weather; they are easily washed off the plants by heavy rain, which is presumably why most infestations occur on the underneath of leaves. Many gardeners still prefer to remove aphid infestations by the use of soapy water.

When insecticides have to be used, the following are all standard recommendations:

(1) Winter washes on fruit trees with tar oils or DNOC to kill overwintering eggs; care must be taken as these oils are very phytotoxic.
(2) Seed dressings with systemic insecticides (menazon, etc.) to protect seedlings in the early stages of growth when they may be most susceptible.
(3) Granules applied bow-wave at time of drilling, or applied later to the young plants (aldicarb, disulfoton, phorate, etc.).
(4) Foliar or soil application of systemic insecticides, such as dimethoate, demeton-*S*-methyl, disulfoton, formothion, menazon, mevinphos, thiometon, etc., or foliar application of suitably formulated granules for foliar lodging. Insecticides with translaminar properties may be very effective.
(5) Foliar application of contact insecticides such as HCH, malathion, deltamethrin, permethrin, pirimicarb, etc.; sprays must reach the underneath of the leaves where many aphids live in order to be effective.
(6) Against glasshouse aphids there is now a microbial aphicide available, reputed to be very effective. The fungus is *Verticillium lecanii*, but is only effective under very moist conditions (more than 85% RH and temperature higher than 15°C) and so is only suitable for use in protected cultivation.

The precise insecticide most suitable for a particular species should be decided after consultation with local Ministry of Agriculture recommendations, as resistance to many chemicals is widespread, some crops may be sensitive to particular pesticides, and not all of the many aphicides are equally effective.

Aphis gossypii Glover

Common name Cotton Aphid (Melon Aphid)
Family. Aphididae
Hosts (main) Cotton
(alternative). *Hibiscus* spp., Cucurbitaceae, many legumes, and a wide range of plants belonging to many different families; polyphagous.
Damage The leaves are cupped or otherwise distorted, with clusters of soft, greenish or blackish aphids on young shoots and on the undersides of young leaves. Drops of sticky honey-dew and/or patches of sooty mould on the upper sides of leaves.
Pest status Outbreaks are common on young plants in spells of dry weather which clear up rapidly with the onset of rain. Plants may be debilitated during the aphid attack but there is no evidence that the yield of seed cotton is affected. It is a greenhouse pest in Europe, especially on cucurbits. Recorded as a vector of about 44 virus diseases.
Life history Only the female adults are found, which may be winged or wingless; blackish-green, small to medium-sized, about 1–2 mm long; antennae usually only about half the length of the body. Siphunculi usually black in colour and cauda not often paler; the eyes are red.

There are probably several other species going under the name of *Aphis gossypii*. The wingless females are somewhat larger, more globular, and generally paler in colour. Living young, greenish or brownish in colour, are produced by both types of adult female. The adults may live for 2–3 weeks and produce two or more offspring each day.
Distribution Completely cosmopolitan, absent only from the colder parts of Asia and Canada (CIE map no. A18).
Control Control measures are not usually required on most crops. DDT tends to result in aphid out-breaks when used frequently, but when mixed with carbaryl the pest is usually kept in check.

If chemical control is required then generally sprays of carbaryl or dimethoate are recommended (see p. 187)

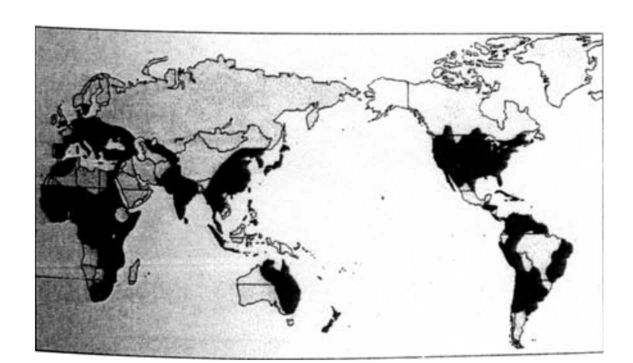
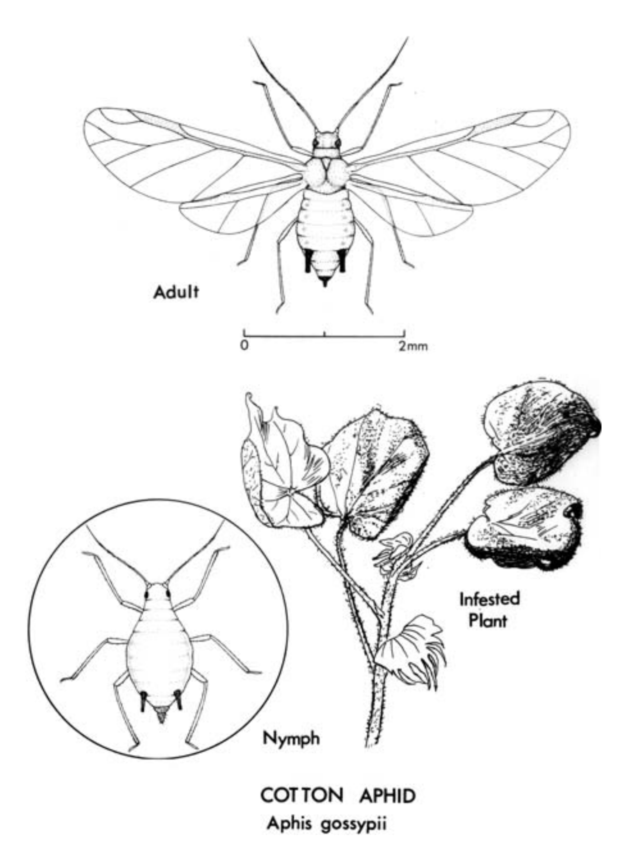
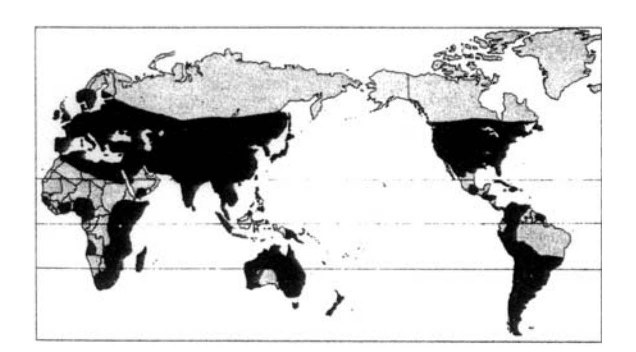


Fig. 9.79. Aphis gossypii (Cotton Aphid); Kenya.



Myzus persicae (Sulz.)

Common name Green Peach Aphid
Family Aphididae
Hosts Polyphagous on many crop plants and weeds.
Damage The direct damage to peach is typically distortion of young leaves and shoots (leaf-curl). On many plants these symptoms are followed by virus disease symptoms.
Pest status A very important pest on many crops in many parts of the world, doing damage both by direct feeding and by virus transmission. It can transmit over 100 virus diseases of plants in about thirty different families, including beans, sugar beet, sugarcane, brassicas, potato, *Citrus* and tobacco.
Life history In the tropics there is no alternation of generations between different hosts, and neither are there sexual forms – males are never found. The females breed by parthenogenesis and vivipary. Most individuals are apterous but winged forms are produced at times for the dispersal of the species. Breeding in warm countries may be more or less continuous but it is basically a temperate species and does not thrive in the tropics.



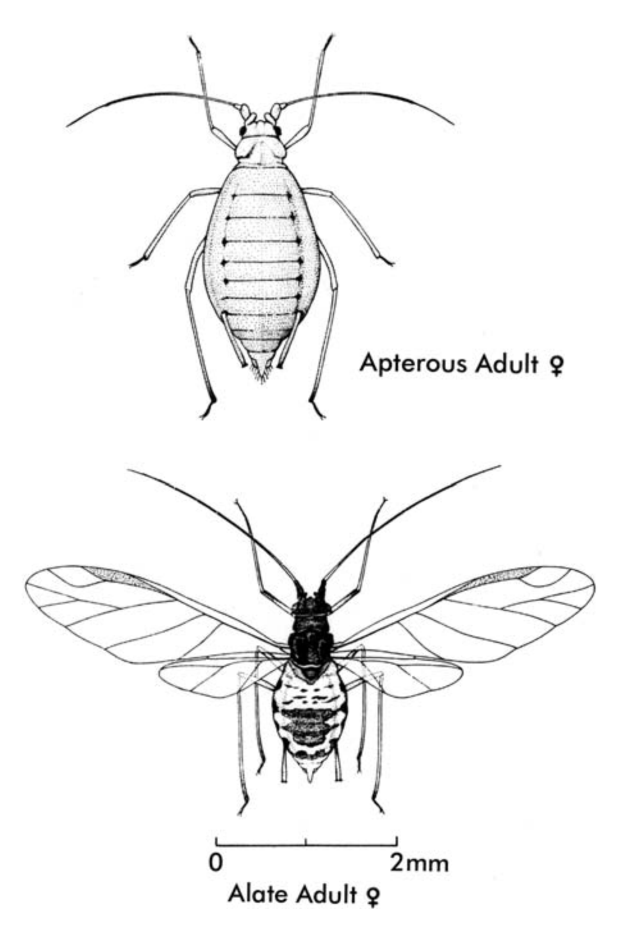
Many physiological races of *M. persicae* have been discovered, showing no morphological differences but distinct host feeding preferences.

The adult is small to medium-sized, 1.25–2.5 mm long, usually green with a darker thorax; antennae two-thirds as long as the body; siphunculi clavate, fairly long; the face viewed dorsally has a characteristic shape.
Distribution Virtually cosmopolitan; northwards up to S. Scandinavia, N. China, and Canada (CIE map no. A45).
Control The use of chemicals to prevent virus spread by controlling their aphid vectors is generally not successful. Thus, there is a special need for the integrated control approach, paying particular attention to predators, parasites, alternate hosts and crop manipulation.

The usual aphicides are as follows: dimethoate, malathion, demeton-*S*-methyl, menazon, demephion, disulfoton, formothion, phorate, phosphamidon, thiometon.

Frequently the use of pesticides results in destruction of predators and parasites, and so great care must be taken in their use.

Fig. 9.80. Myzus persicae (Green Peach Aphid) Adults; Cambridge, UK.



Pentalonia nigronervosa Coq.

Common name Banana Aphid
Family Aphididae
Hosts (main). Bananas (*Musa* spp.)

(alternative). *Alpina*, *Heliconia*, *Colocasia* spp.; *Costus*, *Zingiber*, *Palisota*, and tomato. In greenhouses in Europe.

Damage Direct damage is negligible but this aphid is the vector of the virus causing Bunchy Top Disease. The disease is widespread from Egypt, India, through S.E. Asia to Australia. Symptoms include dark green streaking on the leaves, midrib and petioles, progressive leaf-dwarfing, marginal chlorosis and leaf-curling. Fruit bunches are small and distorted, and the fruit is unsaleable.

Pest status Important as the vector of Bunchy Top Disease, which is serious in Asiatic banana-growing areas, and three other virus diseases.

Life history The adults are small to medium-sized, 1–2 mm in length, brown, with antennae as long as the body. The alate adults have a very prominent dark wing venation; the siphunculi are slightly clavate and quite long.

The aphids are found under the old leaf sheaths at the base of the pseudostem near ground level, as colonies of brown shiny wingless aphids. Ants always accompany the aphid colonies, and they are responsible for establishment of new colonies.

Winged adults are usually produced after about 7–10 apterous generations, and the winged adults migrate to new host plants.

Distribution Distribution is probably coexistent with banana cultivation and is more or less pantropical. (CIE map no. A242).

Control Chemical treatments are generally only effective if accompanied by careful eradication of infested plants.

Suggested pesticides are parathion, phosphamidon, dicrotophos and endrin, which should be sprayed at the plant crown and pseudostem base, below soil level between the outer leaf sheath and stem, and over the surrounding soil.

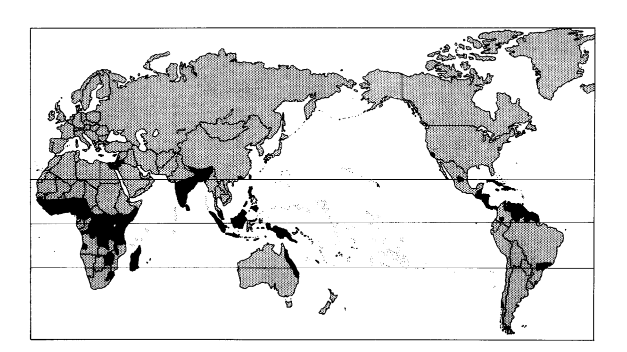
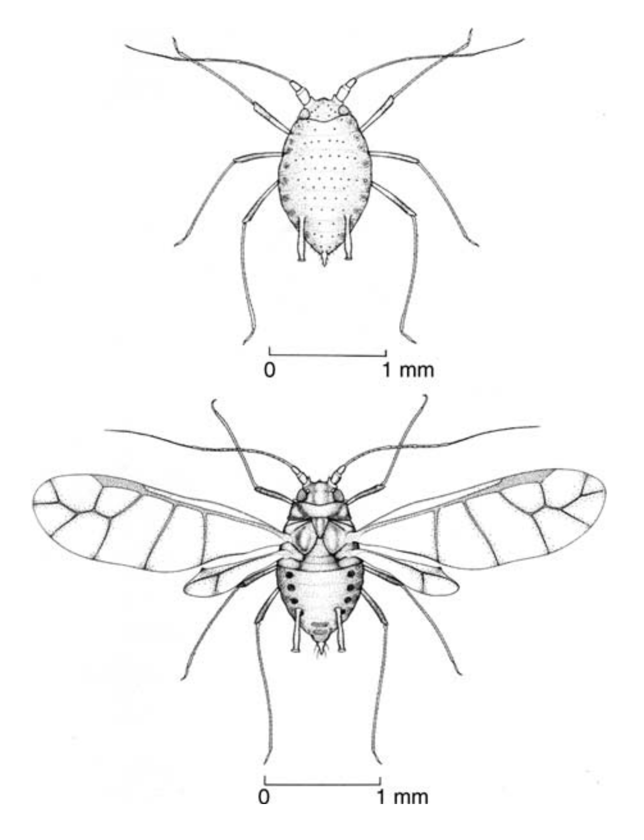


Fig. 9.81. Pentalonia nigronervosa (Banana Aphid).



Rhopalosiphum maidis (Fitch)

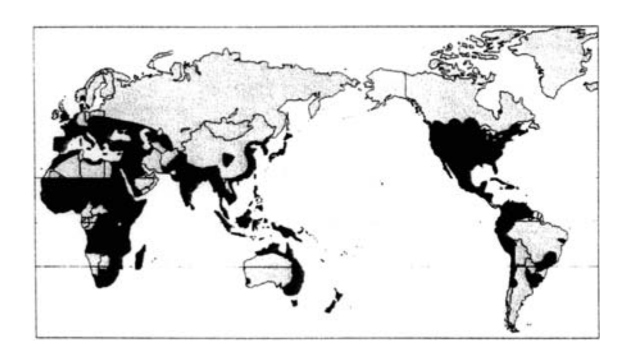
(= *Aphis maidis* Fitch)

Common name Maize Aphid (Corn Leaf Aphid)
Family Aphididae
Hosts (main). Maize

(alternative). Sorghums, millets, sugarcane, wheat, barley, rice, and other Gramineae; manila hemp, tobacco, and other crops and some weeds.

Damage Leaves, leaf sheath and inflorescence covered with colonies of dark green aphids, with a slight white covering. The leaves may become mottled and distorted, and new growth may be dwarfed. The inflorescence may be sufficiently damaged to become sterile. Usually a pest of young tender plants. Honey-dew production is prolific.

Pest status A particularly important pest of cereals in America and parts of Europe. Mostly found on maize and sorghum, occasionally on barley, but seldom found on wheat or oats. It is a vector of many (ten) different virus diseases in cereals and other crops. On wheat in Ethiopia.



Life history Adults may be winged or apterous, about 2 mm long, with characteristically short siphunculi. The cauda is pronounced with long conspicuous setae. There are dark purplish areas around the base of the siphunculi.

Reproduction is mostly or entirely parthenogenetic in most parts of the world, but males are more common in Korea, indicating a probable oriental origin for this species.

The life-cycle in the tropics takes about eight days.

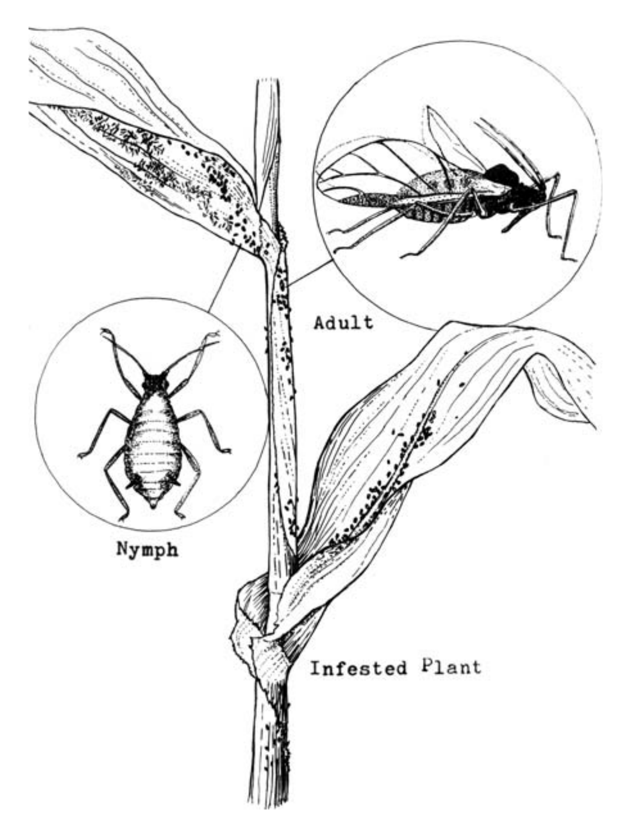
Distribution Almost completely cosmopolitan in distribution, throughout the tropics, subtropics and the warmer temperate regions. The northernmost records are Japan and southern Scandinavia (CIE map no. A67)..

Control Burning the seed crop stubbles after harvest effects a degree of cultural control.

If the plants are growing vigorously the aphids are usually kept under control by natural enemies.

Sprays of dimethoate, demephion, demeton-*S*-methyl, ethoate-methyl, formothion, or menazon are generally effective if required.

Fig. 9.82. Maize Aphid in festation; Kenya.



Toxoptera aurantii (B. de F.)

Common name Black Citrus Aphid
Family Aphididae
Hosts (main). *Citrus* species
(alternative). Other Rutaceae, *Ficus* spp., tea, cocoa, coffee, and other plants; polyphagous.
Damage Distortion of young leaves, with clusters of black aphids on flush growth and under young leaves. Often accompanied by sooty moulds growing on the honey-dew excreted.
Pest status This aphid is universally present on *Citrus* bushes, and occasionally severe outbreaks may occur, especially in dry weather following a rainy season. It is completely polyphagous and has been recorded from 120 different host plants. It also occurs in greenhouses in temperate countries on a range of different hosts.
Life history The adults are shiny black in colour, and may be winged or apterous, from 1.2–1.8 mm in body length, with relatively short antennae. Only females are found, and they produce living young, dark brown in colour, five to seven each day, up to a total of about 50 per female.

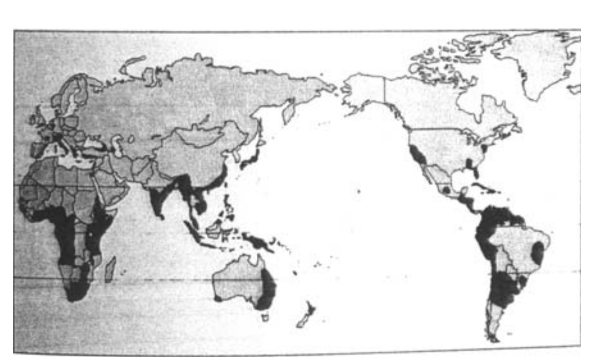
At 25°C a single generation takes as short a time as six days, but at 15°C as long as 20 days, and a similar effect is seen at higher temperatures; at temperatures above 30°C the aphid population declines sharply.

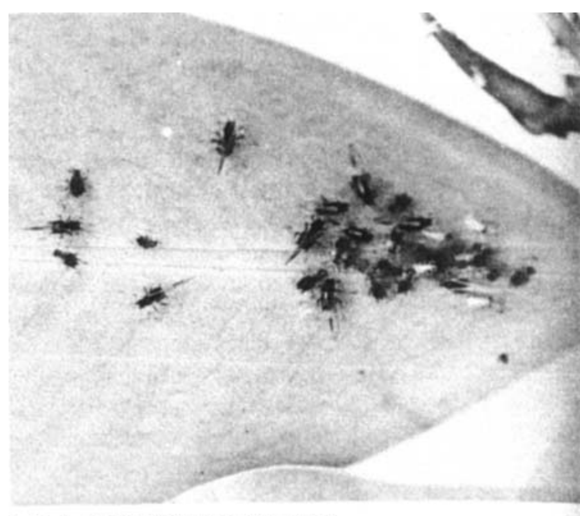
Chemical control should be applied only at periods of flush growth at the first signs of damage. The most successful treatment is often a full-cover spray of dimethoate in water; other systemic insecticides are demeton-*S*-methyl and fenitrothion. Care must be taken to wet the flush leaves. Dimethoate should not be used on rough lemon trees or on nonbudded rough lemon stock.

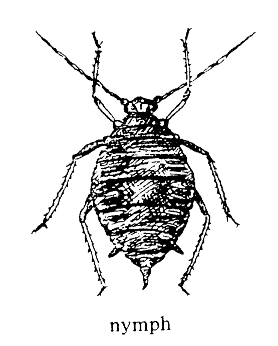
The usual contact aphicides can also be used as an alternative.

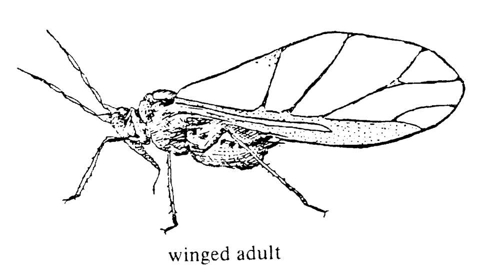
Infestations are generally attended by ants.
Distribution Widely distributed throughout the warmer parts of the world, including S. Europe, Africa, Asia and Australasia, southern USA, C. and S. America (CIE map no. A131).
Control Natural control measures can be encouraged by spray-banding the bushes and tree-trunks with dieldrin to discourage the attendant ants; a large number of predators and parasites have been recorded attacking this species of aphid.

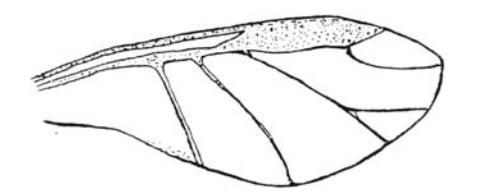
Fig. 9.83. Toxoptera aurantii (Black Citrus Aphid).




infested leaf of *Ficus microcarpa*



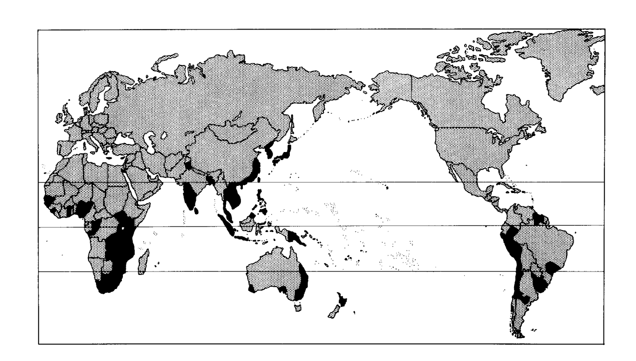




Toxoptera citricidus (Kirk.)

Common name Brown Citrus Aphid (= Tropical Citrus Aphid)
Family Aphididae
Hosts (main). *Citrus* spp.
(alternative). Confined to members of the Rutaceae.
Damage Distortion of young leaves, with clusters of dark brown aphids on flush foliage and under leaves. Sometimes sooty moulds grow on the honey-dew excreted by the aphids. Some twigs and branches show die-back symptoms as this insect is the vector of the virus causing Tristeza (die-back) Disease in Africa and S. America, and also several other virus diseases of *Citrus*.
Pest status A pest species to be found on *Citrus* in most places where it is grown; occasionally serious, especially when virus diseases are transmitted.
Tristeza Disease is common both in tropical Africa and S. America. Sometimes quite small aphid colonies cause serious bud drop after feeding on young flowers. Heavy infestations may regularly produce a yield loss of up to 50%.
Life history Adults are dark brown or blackish in colour, either winged or apterous, about 2.0–2.8 mm in length, and in winged forms the median vein always has two branches. (*T. aurantii* has only one usually, but some specimens from S.E. Asia have two.)

Breeding is through constant viviparity and parthenogenesis, and the time required for one generation may be as short as a week, thus with four generations per month, population growth is tremendous.
Distribution A more tropical and less widespread species than *T. aurantii*, it is found throughout tropical Africa, S.E. Asia, Australasia and S. America (CIE map no. A 132).
Control As for *T. aurantii*, but it is important to prevent the spread of alatae which are responsible for transmitting the virus diseases.



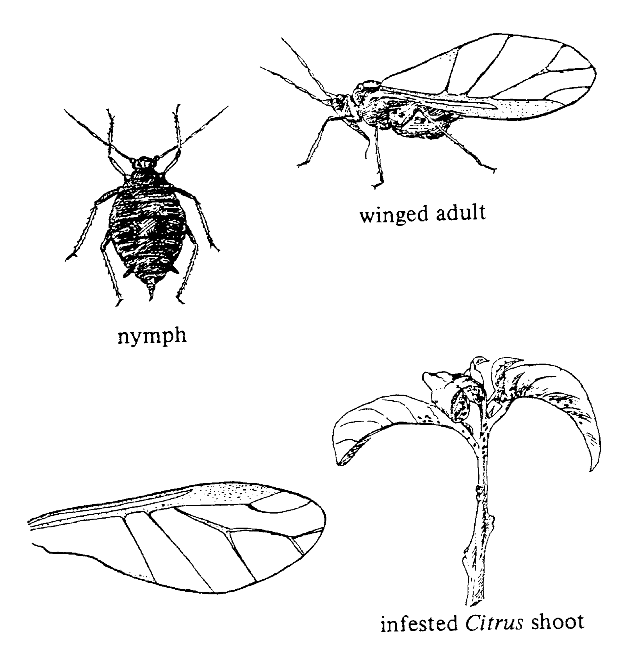


Fig. 9.84. Toxoptera citricidus (Brown Citrus Aphid); Kenya.

Ceratovacuna lanigera Zhnt.
(= *Oregma*; *Cerataphis saccharivora* Mats.)

Common name Sugarcane Woolly Aphid
Family Pemphigidae
Hosts (main). Sugarcane
(alternative). Wild cane (*Saccharum spontaneum*), and *Miscanthus* spp. (Gramineae), Bamboos.
Damage Heavy infestations on the underneath of leaves of white waxy aphids cause a loss of plant sap, and sometimes heavy sooty mould infestation occurs on the foliage. In Taiwan young plants may be killed by heavy infestations.
Pest status Within its area of occurrence it is quite a common pest but does little damage and control measures are seldom required. However it has been recorded causing an estimated 20% loss of yield in China (Kwangsi and Fukien) and Taiwan.
Life history The infesting population normally consists of winged and apterous, viviparous and parthenogenetic females, and each female produces 15–35 young which are copiously covered with waxy filaments.

In China it was found that the population peak was in October and November, when damage to the cane was done, and winged females, produced in the middle of November, moved over to *Miscanthus* grasses growing wild around the sugarcane fields where hibernation took place. The apterae on the sugarcane die in the early frosts. Crop infestations reappeared in June and then declined to a low level after July, presumably because of the summer temperatures.
Distribution From India through mainland S.E. Asia to China and Taiwan, and the Philippines and Java.
Control In the early study in China (1944–5) adequate control was achieved using sprays of nicotine, soap solution and an oil emulsion.

Normally this insect is preyed upon by many species of Coccinellidae, lacewings, lycaenid larvae and syrphid larvae, which together keep most aphid populations in check. In Taiwan (Pan, 1980) the damage to young plants by woolly aphid is sufficiently serious that pesticides have to be used, and adequate control has been achieved by foliar sprays of malathion and demeton-*S*-methyl.

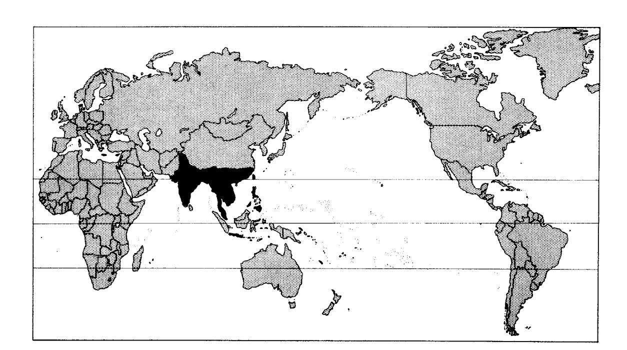
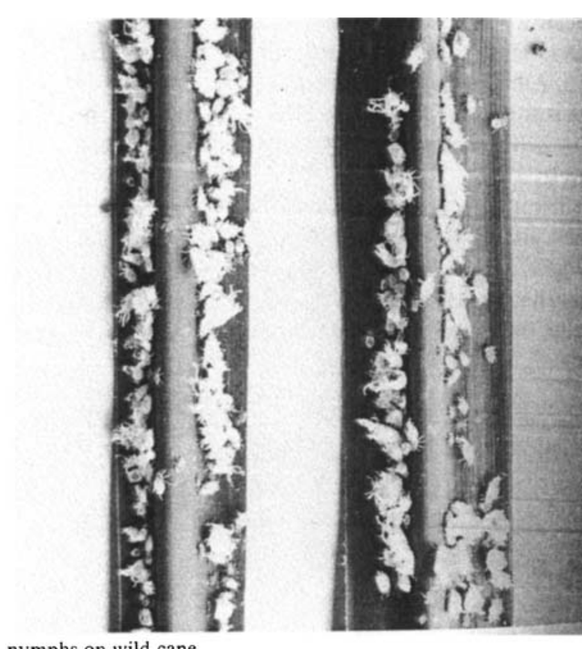


Fig. 9.85. Ceratovacuna lanigera (Sugarcane Woolly Aphid) nymphs on wild sugarcane; S. China.



Pseudoregma bambusicola Tak.

Common name Bamboo Woolly Aphid
Family Pemphigidae
Hosts Only recorded from one or two species of bamboo (*Bambusa* spp.).
Damage Heavy infestations of aphids cover the stem entirely for several internodes; similarly on lateral shoots the plant is entirely obscured by a mass of fat grey aphids, which all wave their antennae frantically when excited. Sometimes the bamboo shoots succumb to this massive infestation and die. Usually though the infestation is spectacular rather than very damaging. Honey-dew excretion is copious and falls like fine rain under a heavily infested tall bamboo, and wasps, beetles, flies, and some butterflies gather to feed on the sugar. Sooty mould infestations are usually very extensive both on and around the infested bamboo stems.
Pest status A striking but minor pest, although the total loss of sap with a severe infestation must be considerable.
Life history No details are known, except that winged adults are seldom seen. The apterous females are large and almost globular, measuring some 4 mm in length, but presumably alatae are produced at some time in the season (probably autumn or early winter) to effect dispersal of the species to new hosts.
Distribution To date only recorded from S. China, where it is very abundant, but may well occur throughout S.E. Asia.
Control Several large Coccinellidae are conspicuous predators and apparently eat large numbers of the aphids.

Chemical control measures are not usually needed.

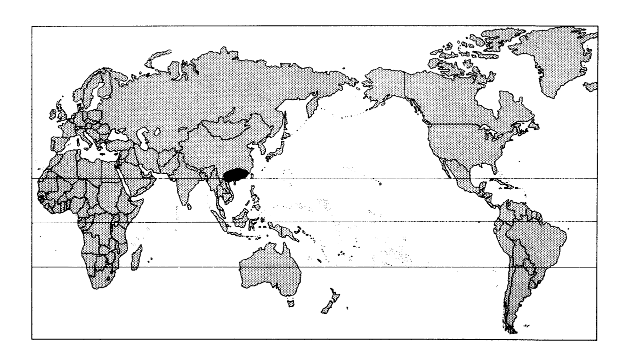
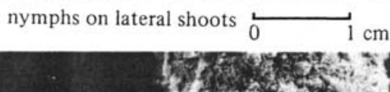
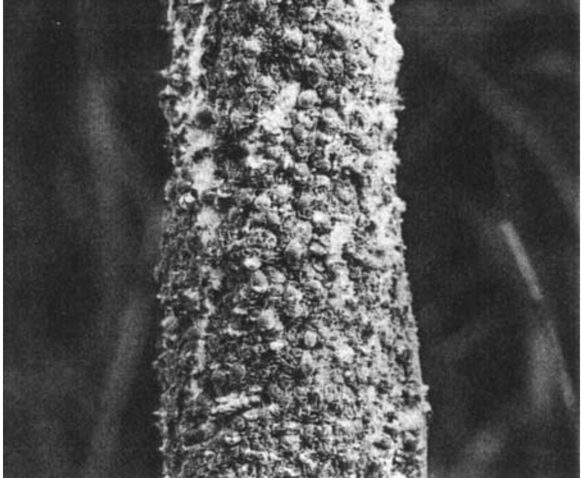


Fig. 9.86. Pseudoregma bambusicda (Bamboo Woolly Aphid) infestation; S.China.



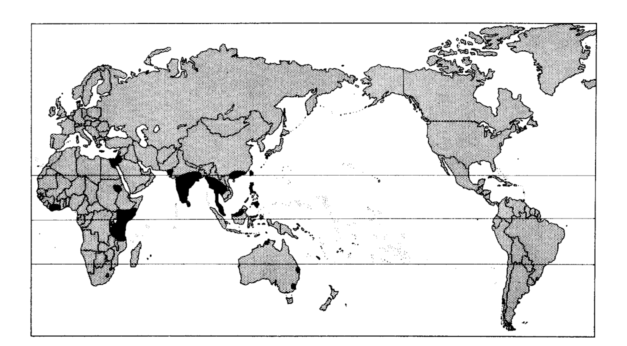




nymphs on main stem

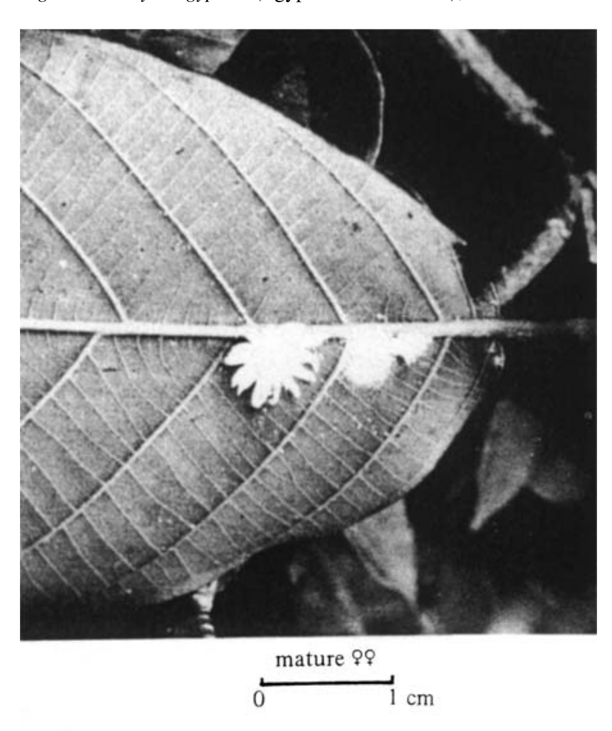
Icerya aegyptica (Dgl.)

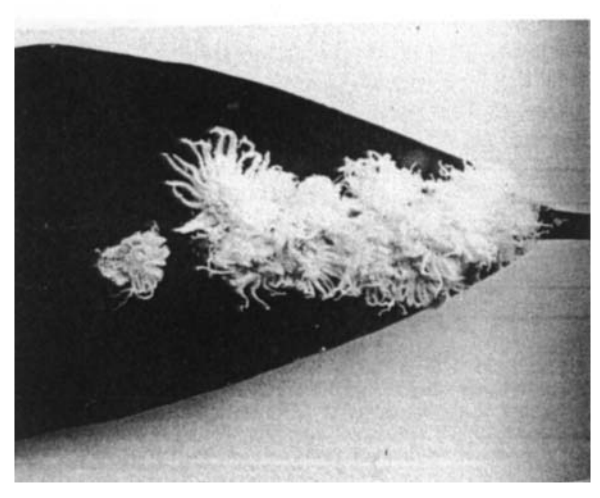
Common name Egyptian Fluted Scale
Family Margarodidae
Hosts Polyphagous in feeding habits, it has been recorded from *Citrus*, coffee, tea, guava, mulberry, wattle, date palm, grapevine, pear, jack-fruit, *Ficus* spp., and many ornamentals.
Damage Usually slight, just a little loss of sap, but the insect is very conspicuous and easily noticed.
Pest status Usually a minor pest, which seldom requires control measures, but it is widespread in the Old World tropics and found on many different plants.



Life history Details of its life history are not available. However, the nymphs are distinguishable from those of *I. purchasi* by having a golden body colour (underneath the wax) as opposed to dark red, and by the long waxy fringes festooning the body surface. Body size is generally about 6 mm in length by 4 mm breadth. The larvae are scarcely distinguishable from *I. purchasi* morphologically.
Distribution Widespread throughout the Old World tropics (CIE map no. A221).
Control Usually preyed upon by many different Coccinellidae, and seldom requires chemical control.

Fig. 9.87. Icerya aegyptica (Egyptian Fluted Scale); S.China.





Mealybugs and scale insects
(Homoptera; Coccoidea)

This superfamily contains the mealybugs and scale insects (*sensu lato*); a large group which is most important in the warmer parts of the world, but is widespread in N. America and in greenhouses in northern Europe. Generally, it may be said that the aphids are the main temperate bug pests and the scale insects (and mealybugs) the main tropical bug pests of agriculture on a world basis.

The hosts are mostly woody plants (trees and shrubs), but some species attack herbaceous plants and Gramineae. The crops most heavily attacked by both mealybugs and scale insects are undoubtedly citrus and coffee, and the various palms (Palmae). Some species are quite host-specific and are found only on *Citrus* for example, but others are polyphagous and on many different woody plants.

Field determination to genus is difficult as the main taxonomic character is chaetotaxy, so only tentative field identifications are feasible, especially as many trees will be host to several different, closely related mealybugs and scales.

The life-cycle is unusual in that the females are degenerate, apterous, obscurely segmented, with atrophied appendages and a scale-like body with either a waxy or powdery coating. Adult males are small, usually two-winged (hindwings lost), and with long antennae; in some species males have never been recorded. Females are oviparous or viviparous and the newly hatched nymphs usually shelter under the dead female 'scale' for a while. Eggs are laid under the 'scale' of the female, and by the time oviposition has ceased the female is dead and shrunken, but the eggs and the newly hatched young are protected physically. The minute first-instar nymphs are termed 'crawlers' and are the dispersive stage, having well-developed legs and being very active, and small enough to be carried on air currents.

Mealybugs retain a measure of mobility, even as adults, but the scales settle as nymphs on either twigs, fruit or leaves, and once their mouthparts ('stylet') are inserted into the host phloem system most species are immobile. In a number of species it is usual for young nymphs to feed on leaves and then to migrate to their permanent site on twigs. Some are typically found on the fruits of the host plant.

Many Coccoidea are honey-dew excretors which means that their infestations are usually attended by ants and associated with sooty mould infestations.

Predators and parasites are important in controlling many populations, especially the predacious Coccinellidae and parasitic Hymenoptera, and care has to be taken in any management programme not to upset the usually high level of natural control being exerted.

Important Pest Species of Coccoidea

In addition to the species already specifically mentioned, the following are pest species that occur in the cooler parts of the world and are of some importance as agricultural pests.

Pseudococcidae (Mealybugs)

Dysmicoccus boninsis (Kuw.) – (Grey Sugarcane Mealybug) on sugarcane and Gramineae; New World, Japan, Egypt, Australia (CIE map no. A.116).
Dysmicoccus brevipes (Ckll.) – (Pineapple Mealybug) polyphagous: cosmopolitan in tropics and sub-tropics (CIE map no. A.50).
Planococcus citri (Risso) – (Citrus Mealybug) polyphagous; cosmopolitan in the warmer parts of the world, and in greenhouses in Europe and N. America (CIE map no. A.43).
Phenacoccus aceris (Sigm.) – (Apple Mealybug) on apple; USA, Europe and now recorded in the UK.

Margarodidae (Fluted scales)
This small group is mostly tropical in distribution, but *Icerya purchasi* does occur in warmer temperate regions as well as the tropics.
Drosicha spp. – (Giant 'Mealybugs') polyphagous; in tropical Asia.

Coccidae (Soft scales)

Ceroplastes rubens Mask. – (Pink Waxy Scale) polyphagous: India, China, Japan, Australia, E. Africa (CIE map no. A.118).
Chloropulvinaria psidii (Mask.) – (Guava Mealy Scale) polyphagous; cosmopolitan in warmer regions (CIE map no. A.59).
Coccus hesperidum L. – (Soft Brown Scale) polyphagous on trees and shrubs; cosmopolitan in warmer climates (CIE map no. A.92).
Coccus viridis (Green) – (Soft Green Scale) polyphagous on trees and shrubs; pantropical (CIE map no. A.305).
Coccus spp. – (Soft Scales) several species on various hosts in the USA and Asia.
Eulecanium tiliae (L.) – (Hazelnut Scale) on hazelnut, apple, pear, etc.: Europe.
Gascardia destructor (Newst.) – (White Waxy Scale) polyphagous on trees; Australasia, Florida, and southern Africa (CIE map no. A.117).
Mesolecanium nigrofasciatum Pergande – (Terrapin Scale) polyphagous on woody hosts; Canada and USA.
Pulvinaria ribesiae Sigm. – (Woolly Currant Scale) on currants, gooseberry and rowan; Europe.
Pulvinaria vitis (L.) – (Woolly Vine Scale) on grapevine, peach, apricot; Europe.
Pulvinaria spp. – (Cottony Scales) on fruit and other trees; Europe, USA and Canada.

Diaspididae (Armoured scales)

Aonidiella aurantii (Maskell) – (California Red Scale) polyphagous on a wide range of hosts; cosmopolitan in warmer regions (CIE map no. A.2).
Aonidiella spp. – on many different host plants; USA.
Aspidiotus hederae Bouché – (Oleander Scale) on olive, apple, mango, palms, citrus, oleander (polyphagous); cosmopolitan (CIE map no. A.268).

Aspidiotus destructor Sign. – (Coconut Scale) polyphagous; pantropical (CIE map no. A.218).
Chionaspis furfura (Fitch) – (Scurfy Scale) polyphagous on fruit trees; USA and Canada.
Chrysomphalus aonidum (L.) – (Purple Scale (Florida Red Scale)) polyphagous on both monocotyledons and dicotyledons: pantropical (CIE map no. A.4).
Chrysomphalus dictyospermi (Morgan) – (Spanish Red Scale) polyphagous on fruit trees and shrubs; cosmopolitan in warmer regions (CIE map no. A.3).
Pseudaulacaspis pentagona (Targ.) – (White Peach Scale) polyphagous on fruit trees; cosmopolitan in warmer regions (CIE map no. A.58).

Control of mealybugs and scale insects
(Coccoidea)

Mealybugs and their close allies have the body surface covered with wax, often as a thick flocculent layer, which affords considerable protection against contact insecticides as the body is virtually unwettable. Similarly the scales have an expanded dorsal shield under which the body is sheltered. Thus the mature females and the larger nymphs are difficult to kill with contact insecticides, even when extra wetters are added to the sprays. Systemic insecticides can be used, but success is generally minimal. The only stage really vulnerable is the first-instar 'crawler', and this stage persists for only a few days.

Natural control is usually very important in most orchards, and in the past careless use of broad-spectrum insecticides, such as DDT, led to many pest population resurgences and outbreaks, especially of aphids, scale insects and spider mites. These population outbreaks were due entirely to the accidental destruction of the natural predators and parasites.

Most orchard crops are now carefully managed with an IPM approach, and the different aspects to be considered are mentioned below.

(1) **Cultural control**
- (a) Phytosanitation – heavily infested fruit trees are often best left alone to permit the parasites to emerge.
- (b) Clean planting material – all new planting material should be pest-free (use oils, fumigation, washing or hot-water treatment).

(2) **Biological control**
- (a) Natural control – allow some trees to remain unsprayed on alternate years, to permit parasite populations to survive and build up. Use of sticky bands or spray banding to keep ants out of the tree allows the parasites to be more effective.
- (b) Biological control – supplementation of existing natural control by introducing predators or parasites; especially important to fill any gaps in the local spectrum of predators and parasites.

(3) **Pesticides**
- (a) Winter (dormant) washes with tar oils or DNOC, on deciduous trees, against overwintering scales and eggs; generally very successful.
- (b) Spring sprays of petroleum or white oils against young nymphs, but care must be taken for these oils are basically phytotoxic.
- (c) Contact insecticides against young nymphs, using malathion, diazinon or fenitrothion – usually two sprays at 14-day intervals are required.

Icerya purchasi Mask.
(= *Pericerya purchasi* Mask.)

Common name Cottony Cushion Scale (Fluted Scale)
Family Margarodidae
Hosts (main). *Citrus* spp.

(alternative). Polyphagous; attacking many other plants, especially mango and guava, and forest tree seedlings.

Damage The twigs are infested with large, white, fluted scales, and infested leaves often turn yellow and fall prematurely. Heavily infested young shoots are killed, and in fact whole nursery trees can be killed. Copious quantities of honey-dew are excreted.

Pest status A polyphagous pest, important on *Citrus*, very widely distributed throughout the world.

This pest is a native of Australia, introduced into California in 1868, and now occurring in all *Citrus*-growing areas.

Life history The adult female is a distinctive insect, being quite large (about 3.5 mm), sturdy, with a brown body covered with a layer of wax. The most conspicuous part of the insect is the large, white, fluted egg-sac which is secreted by the female. The egg-sac usually contains more than 100 red, oblong eggs. The hatching period is from a few days to two months, according to climate.

The three nymphal stages are shiny, reddish insects under the wax, and they are most abundant along the midrib under the leaves. The fully grown scales are most frequently found on the twigs and shoots.

Males are seldom found, but sexual differentiation occurs during the second nymphal instar.

Distribution Cosmopolitan through the warmer parts of the world; only unrecorded from a few countries (CIE map no. A51).

Called the Fluted Scale in the USA.

Control This scale is usually controlled naturally by Coccinellidae which have been introduced from Australia and India into most *Citrus* growing areas.

If chemical control is required then azinphos-methyl or parathion-methyl should prove effective.

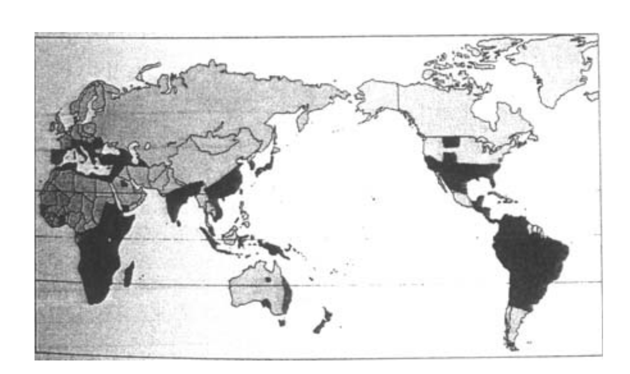




Fig. 9.88. Icerya purchasi (Cottony Cushion Scale); Kenya.



Icerya seychellarum (Westw.)

Common name Seychelles Fluted Scale
Family Margarodidae
Hosts Polyphagous; recorded attacking *Citrus*, guava, jack-fruit, mango, pear, most species of Palmae, and many other crops and ornamentals.
Damage Usually slight, but a conspicuous insect producing unsightly infestations, and leaving fruits covered with waxy exudates.
Pest status A very widespread and polyphagous but minor pest, which does not often require special control measures.
Life history Details are not available, but it is expected to be basically similar to other species of *Icerya*.
Distribution Very abundant in Madagascar, but only recorded from a few localities on mainland Africa; otherwise Seychelles, Mauritius, Sri Lanka, parts of India and S.E. Asia up to China and Japan (CIE map no. A52).
Control Chemical control is normally not required; as with other species of *Icerya* numbers are usually kept under control by predation of adults and larvae of several species of Coccinellidae.

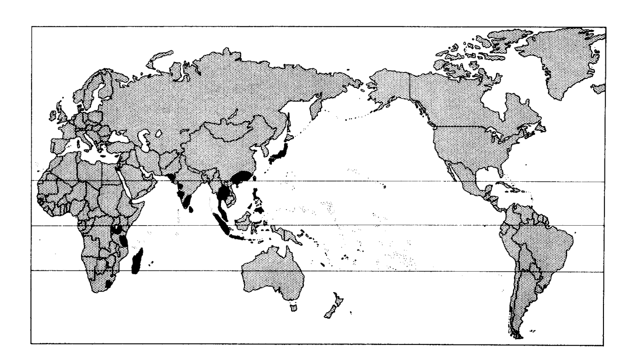
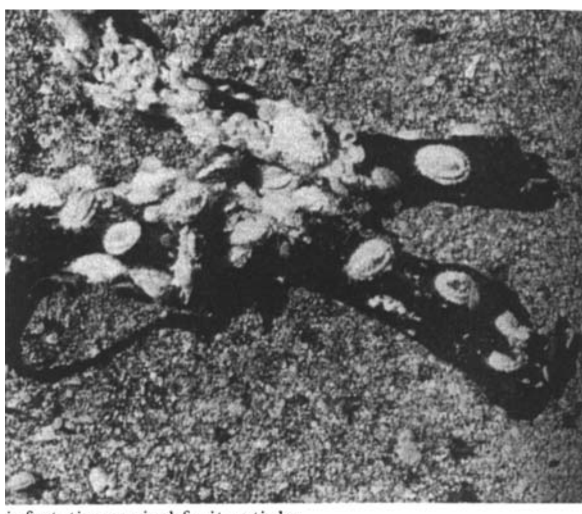


Fig. 9.89. Icerya seychellarum (Seychelles Fluted Scale); S. China.



Orthezia insignis Browne

Common name Jacaranda Bug (Lantana Bug)
Family Orthezidae
Hosts (main) Coffee, mainly *arabica*.
(alternative). *Jacaranda*, *Citrus*, *Lantana*, sweet potato, eggplant, and many other plants, especially roses and tomato.
Damage The bugs are found sitting on the leaves, shoots, and fruit of the host plant. The damage consists of sap removal by the feeding bugs and is not in itself evident.
Pest status A polyphagous pest on many crops and plants but seldom serious on any of them. It is not well adapted to coffee and does not usually stay long on the bushes. There are some records from greenhouses in Europe and N. America.
Life history Not well known.
Distribution Probably pantropical, but records from Asia are restricted to S. India, Sri Lanka, and Malaya, and there are none from Australia (CIE map no. A73).
Control Not usually required. Can be used as a B.C agent for controlly Lantana.

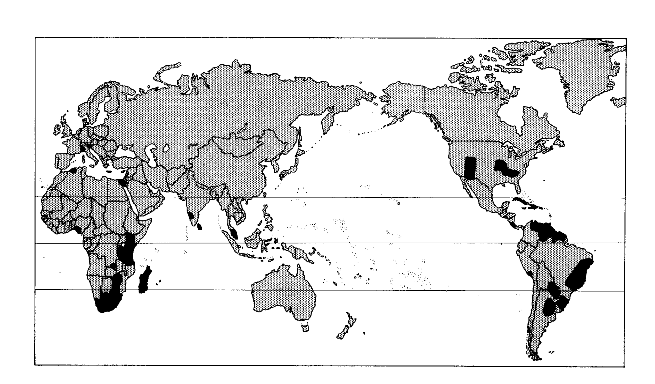
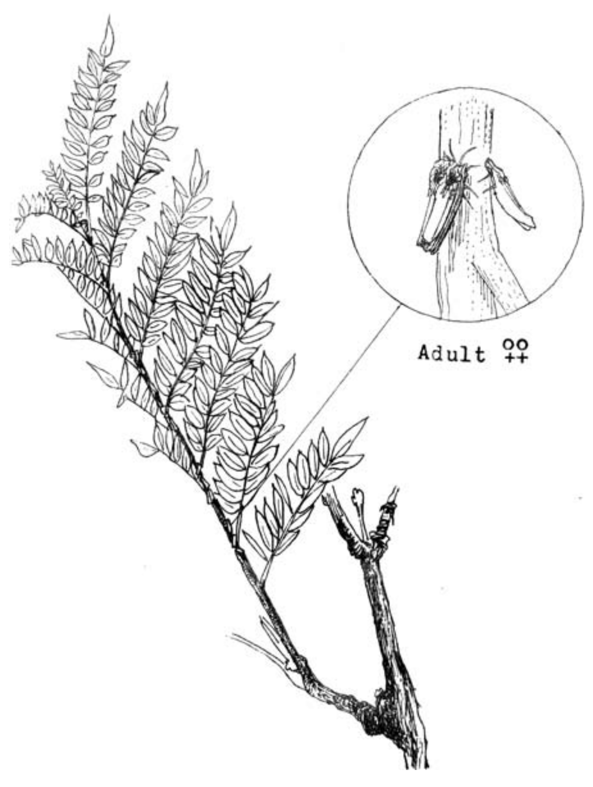


Fig. 9.90. Orthezia insignis (Jacaranda Bug); Kenya.



Dysmicoccus brevipes (Ckll.)

Common name Pineapple Mealybug
Family Pseudococcidae
Hosts (main). Pineapple

(alternative). Also recorded from sugarcane, groundnut, coconut, coffee and *Pandanus*.

Damage This is a particularly important pest as it is a vector of the Mealybug Wilt virus. The first symptoms of the disease usually appear in the roots which cease to grow, collapse and then rot. An apparently flourishing crop will show the symptoms earlier than a slow growing, poor crop. This is known as Quick Wilt.

Pest status *D. brevipes* is a serious pest of pineapple wherever they are grown. Some varieties of pineapple are more resistant to the virus than others, the variety Cayenne being highly susceptible. It is a polyphagous pest, often found on the roots of the crops it attacks.

Life history The mealybugs live in colonies underground with only a small proportion living on the leaves. The occurrence of Mealybug Wilt is largely correlated with the subterranean colony on the roots.

The aerial individuals are to be found mostly at the base of the leaves, which may have to be spread in order to make the bugs evident.

Distribution Almost completely pantropical in distribution, with a few records from subtropical areas (CIE map no. A50).

Control Spraying the leaves does not control the spread of the disease, as there is only a small proportion of the colony on the leaves at any time.

Control can be obtained by dipping the slips in a solution of malathion, diazinon, or parathion, and stacking the slips vertically for 24 hours to allow the insecticide to accumulate at the leaf bases, and then spraying each month at the base of the plant with parathion.

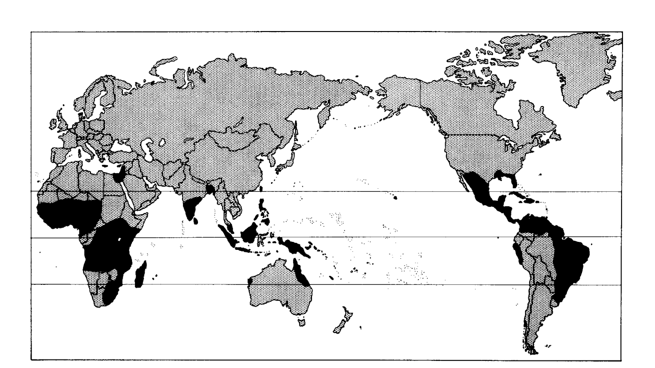


Fig. 9.91. Dysmicoccus brevipes (Pineapple Mealybug); Kenya.



Ferrisia virgata (Ckll.)
(= *Ferrisiana virgata* (Ckll.)) etc.

Common name Striped Mealybug
Family Pseudococcidae
Hosts (main). Coffee

(alternative). Cocoa, *Citrus*, cotton, jute, groundnut, beans, cassava, sugarcane, sweet potato, cashew, guava, tomato, and many other plants.

Damage This insect feeds on young shoots, berries and leaves, sometimes in very large numbers. In dry weather it may move down below ground and inhabit the roots. It is generally accepted that this mealybug is favoured by dry weather; many records refer to heavy attacks following periods of prolonged drought.

Pest status A polyphagous pest on many crops. Vector of Swollen Shoot disease of cocoa. A serious pest on coffee in some areas (Java and Papua New Guinea).

There are many synonyms for this species.

Life history The female lays 300–400 eggs, which hatch in a few hours, and the young nymphs move away quite rapidly. The nymphs are full grown in about six weeks.

The adult female is a distinctive mealybug with a pair of conspicuous longitudinal submedian dark stripes, and long glassy wax threads, and a pronounced tail, and a powdery waxy secretion.

The entire life-cycle takes about 40 days.

Distribution Pantropical in distribution, but with only a few records from Australia and S. America (CIE map no. A219).

Control If control is required the usual insecticides employed against mealybugs can be used. These include malathion, azinphos-methyl and fenitrothion.

As is usual with mealybugs it is important to make sure that the insecticide reaches the body of the insect, so it is necessary to add extra wetter to the spray solution.

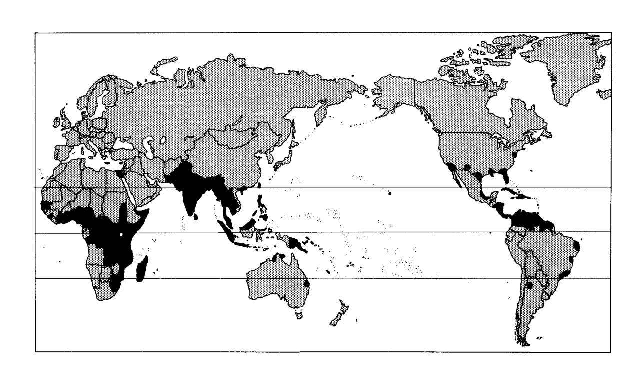
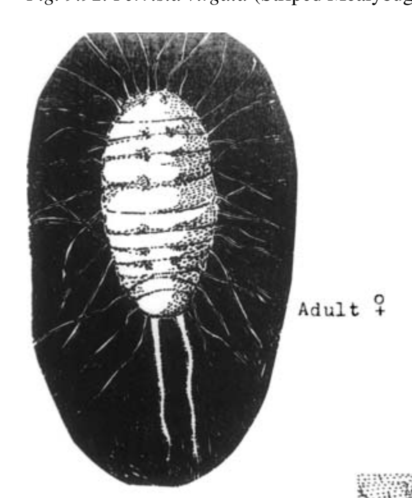
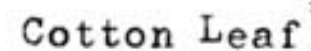


Fig. 9.92. Ferrisia virgata (Striped Mealybug); Kenya.





Maconellicoccus hirsutus (Green)
(= *Phenacoccus hirsutus* (Green))

Common name Hibiscus Mealybug
Family Pseudococcidae
Hosts (main). Plants in the Family Malvaceae, notably *Hibiscus* and *Gossypium* spp.; a polyphagous pest.

(alternative). Leguminosae, and both tropical and subtropical fruit and shade trees, including Citrus, mango, guava and grape.

Damage This mealybug is remarkable in being the only recorded species that has toxic saliva, and whose feeding results in the stunting and sometimes death of the young infested shoots.

Pest status Because of the toxic saliva this can be a serious pest, as heavy infestations of young shoots will often kill the shoots completely, resulting in stunted and deformed bushes and trees. Infestations are often very heavy, and characteristic in appearance due to the shortened internodes of apical shoots, which often swell and develop a dark green colour. The leaves on these shortened shoots give the plant a 'bushy-top' appearance.

Life history The adults are small (about 3 mm in length) and pink in body colour, but covered with a waxy secretion; the waxy filaments are very short and in general the insect resembles *Planococcus* in appearance.

Distribution Found mostly in India and S.E. Asia, to S. China and Taiwan, but recorded from some parts of Africa (CIE map no. A100).

It was accidentally introduced into Hawaii in 1983 and Caribbean in the early 1990s; now extended into C. America and California, where it is widespread and damaging to many plants. (Kairo, et al., 2000).

Control For chemical control either malathion, diazinon, parathion, or azinphos-methyl can be used as foliar sprays, but because of the waxy body covering on the mealybugs it will probably be necessary to add extra wetter to the spray solution.Probably a second spray will be required two weeks later.

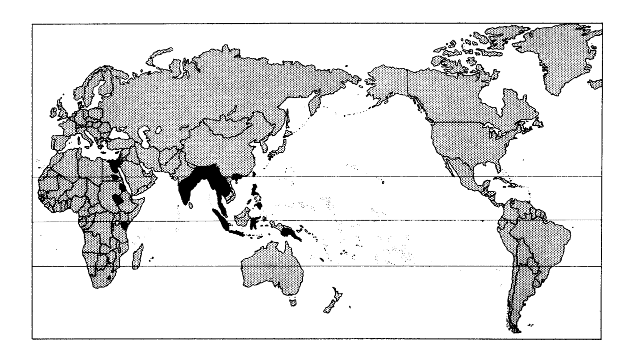
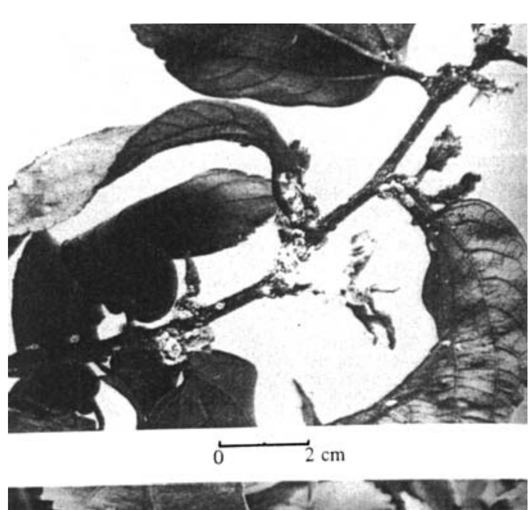


Fig. 9.93. Maconellicoccus hirsutus (Hibiscus Mealybug); S. China, on *Celtis* and *Hibiscus*.





infested (dying) *Hibiscus* shoot

Planococcus citri (Risso)
(= *Pseudococcus citri* (Risso))

Common name Citrus Mealybug (Root Mealybug)
Family Pseudococcidae
Hosts (main). Coffee, *Citrus*, and cocoa.
(alternative). Minor pest of cotton, and various vines.
Damage The leaves wilt and turn yellow, as if affected by drought. Roots are often stunted and encased in a crust of greenish-white fungal tissue, *Polyporus* sp. If the fungus is peeled off the white mealybugs can be seen. The aerial form is found on leaves, twigs, and at the base of fruit. A major virus vector
Pest status A minor pest of *arabica* and *robusta* coffee; occasional trees are killed, especially very young trees. Another race of *P. citri* is sometimes found on the aerial parts of the coffee trees, but very rarely causes serious damage; this race is common on *Citrus* and sometimes on cotton. Generally a polyphagous pest; occurs in greenhouses in temperate climates.
Life history Eggs (150–300) are laid in the female ovisac, at tave 3–5 days to develop. Nymphal instars take 16–38 days. Reproduction is seasonal, and the adult sex ratio is 1:1. There are two basic forms the root dwellers and the aerial form. Five or more generations per year. Root Mealybugs are sometimes found without the fungus. This suggests that the plant is first weakened by the feeding of the mealybug; the debilitated plant is then susceptible to fungal attack.

Citrus Mealybug is a vector of Swollen Shoot (virus) Disease of cocoa.
Distribution Almost completely pantropical and also extending well into subtropical regions (CIE map no A43).

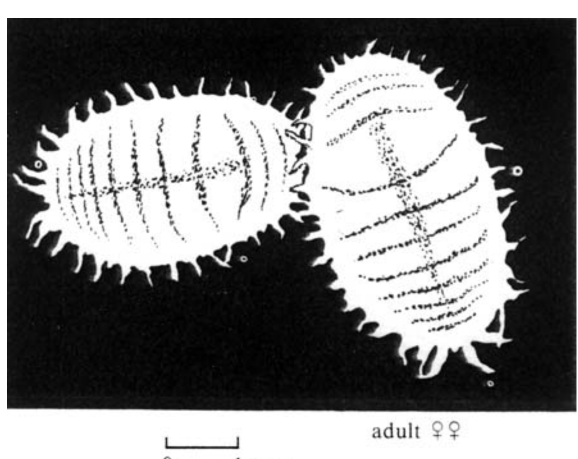
Occurs in greenhouses in temperate countries.
Control Trees with green or yellow leaves can often be saved by careful treatment, though recovery is very slow. Trees with dead brown leaves are past hope and should be uprooted and replaced.

The soil under the tree should be dusted with aldrin, especially round the collar; the insecticide should be worked into the top layers of the soil. A generous layer of mulch and irrigation should also be provided round the infested trees after treatment.

When gapping up in an attacked plantation aldrin dust should be mixed with the soil in the planting hole.

Sprays of diazinon, malathion, parathion and dimethoate may be effective, especially if the malathion or parathion is mixed with white oil.

Fig. 9.94. Planococcus citri (Citrus/Root Mealy bugs); Kenya.



Planococcus kenyae (Le Pelley)
(= *Pseudococcus kenyae* Le Pelley)

Common name Kenya Mealybug
Family Pseudococcidae
Hosts (main). Coffee

(alternative). A large number of wild and cultivated plants, including yam, pigeon pea, passion fruit, sugarcane and sweet potato.

Damage Mealy white masses of insects, especially between clusters of berries or flower buds or on sucker tips. Upper surface of leaves with spots of sticky transparent honey-dew, or covered with a crust of sooty mould growing on the honey-dew.

Pest status Between 1923 and 1939 it had been a major pest of *arabica* coffee in the East Rift area of Kenya, but since the liberation of parasites from Uganda in 1938 it has been reduced to a minor pest.

Life history Eggs are laid below and behind the mature female and are covered with a waxy secretion. One female may lay between 50 and 200 eggs. Females are usually fertilized by the winged males but this is not essential for fertile egg production.

The larva is flat and oval, pale brown, with six short legs; there is no wax on the body. It crawls upwards until it finds a place where a large part of its body is in contact with a surface, e.g. between the stalks of young berries or buds, or next to other mealybugs. Here it begins to feed and gradually develop the characteristic mealy wax covering. It passes through three nymphal stages before becoming adult, each stage being larger, more convex and more waxy but otherwise differing little from previous stages. It may change its position and move a short distance if conditions are becoming unfavourable, especially during the third stage. In the laboratory the female can complete her development and begin egg-laying after 36 days. The males are rarely seen and cause negligible damage. In the egg and first two stages they resemble the corresponding stages of the female. At the end of the second instar they seek out a crevice (commonly in the bark) and there turn into the so-called ‘pre-pupal’ stage. This is followed by another resting or ‘pupal’ stage from which emerges a fragile two-winged insect – the adult male. These infestations are usually attended by ants that feed on the honey-dew.

Distribution E. Africa, Nigeria, Zaïre, and Ghana (CIE map no. A384).

Control Prompt stripping of unwanted sucker growth helps to reduce the number of suitable feeding sites.

The bug is best controlled indirectly; banding the stump of the tree with dieldrin keeps off the attendant ants and allows the natural enemies to clean up the infestation. The band, which may be painted on or sprayed, should be at least 15 cm wide and any bridges such as drooping primaries which would allow the ants to by-pass the band must be removed.

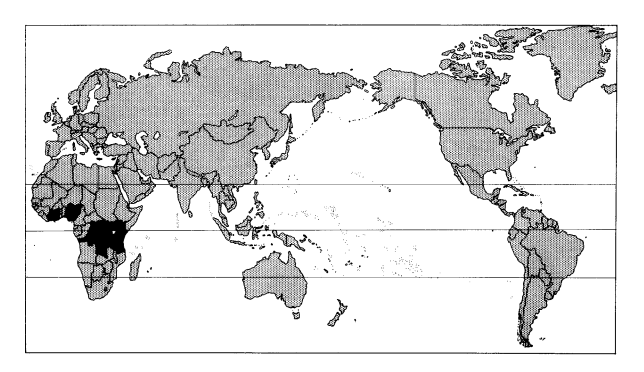
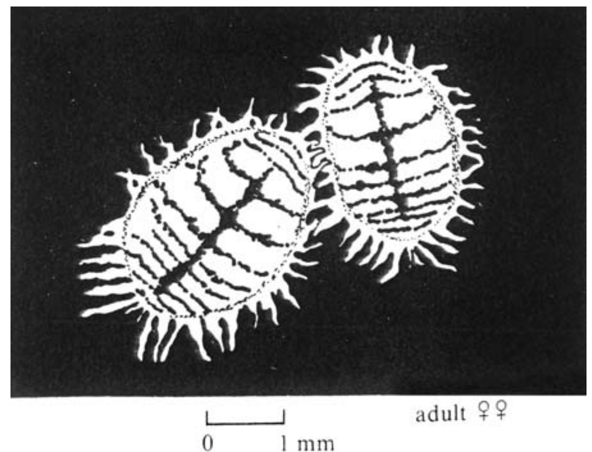


Fig. 9.95. Planococcus kenyae (Kenya Mealybug); Kenya.



Pseudococcus longispinus T.
(= *P. aonidum* (Li)

Common name Long-tailed Mealybug
Family Pseudococcidae
Hosts (main). *Citrus* spp.

(alternative). Coffee, cocoa, sugarcane, coconut and other palms; frequent on ornamentals and other crops; a polyphagous pest.

Damage The waxy mealybugs are congregated near the tips of shoots, on the fruit, or on the leaves. By sucking the sap a heavy infestation can kill young plants. Some leaf and shoot deformation is not uncommon.

Pest status Usually not a serious pest on any one crop, but very widespread and common on many crops and plants.

Life history The adult female lays an egg mass of up to 100 or 200 eggs.

The young nymphs crawl away from the egg mass to find suitable feeding sites. After about 20 days the sexes become distinguishable, and the males aggregate separately, forming rough cocoons in which they become a quiescent third instar with small wing buds. After moulting again they become fourth instars with more developed wing buds. From cocoon formation to emergence of the winged males is about 10–14 days. The second instar female nymphs moult into the last immature stage. As the nymphs grow larger they gradually produce more wax. The function of the males is not known, parthenogenesis being assumed.

The adult female mealybugs are long-tailed, in that they have a pair of long filamentous posterior waxy projections (tassels). There are however several other species which have these long tassels so this character is not specific.

Ants are usually associated with the mealybugs and they feed on the honey-dew excreted by the bugs.

Distribution Very widely distributed – almost cosmopolitan (CIE map no. A93), revised.

Control This pest does not often require controlling.

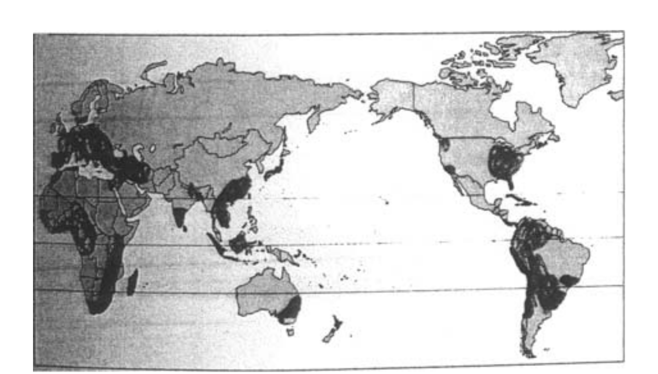
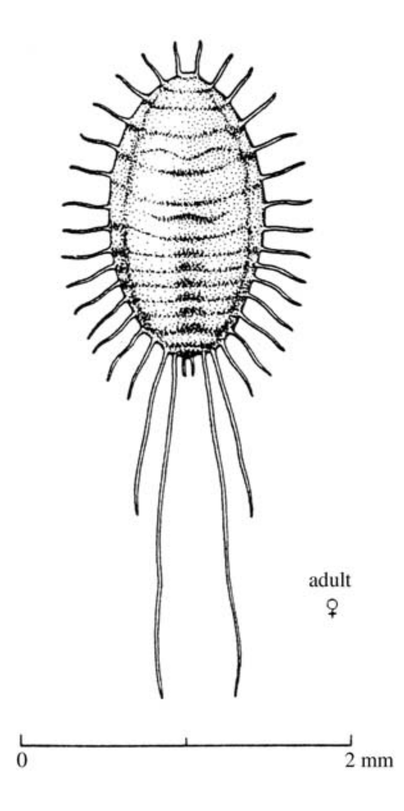
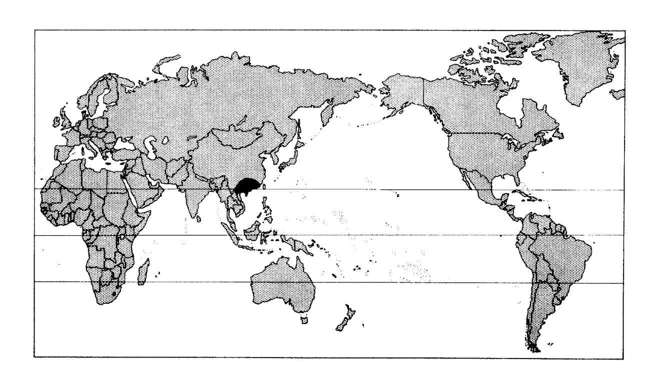


Fig. 9.96. Pseudococcus longispinus (Long-tailed Mealybug); S. China.



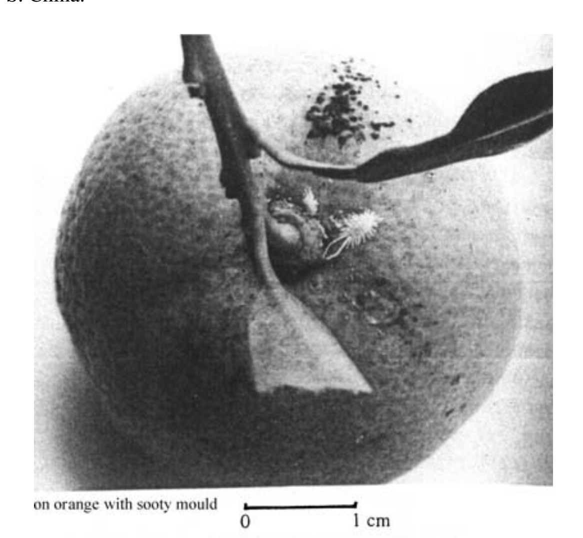
Pseudococcus citriculus Green

Common name Long-tailed Citrus Mealybug
Family Pseudococcidae
Hosts (main). *Citrus* spp. and other Rutaceae.
(alternative). *Hibiscus*, *Ficus* spp., various orchids and other ornamentals.
Damage A polyphagous pest often found in small numbers, doing little obvious damage, but producing copious honey-dew which results in heavy sooty mould infestations on the foliage.
Pest status Only a minor pest but conspicuous and widespread in S. China and usually with a disproportionate amount of sooty mould on the foliage and fruits.



Life history Details are not known. The adult is a small mealybug, about 3 mm in body length, with quite long lateral waxy filaments but with two very long anal filaments of wax. Usually attended by ants. On a worldwide basis there are several other species of mealybugs with long 'tails' to be found on *Citrus* plants.
Distribution To date only recorded from S. China.
Control If required, the usual pesticides effective against mealybugs can be used, but repeated sprays will probably be needed. Predation by natural enemies is often quite high, and this can be encouraged by banding the trees with dieldrin-soaked cloth (or spray-banding) which will repel the attendant ants.

Fig. 9.97. Pseudococcus citriculus (Long-tailed Citrus Mealybugs); S. China.



on orange with sooty mould



on leaf of *Ficus elastica*

Saccharicoccus sacchari (Ckll.)

Common name Pink Sugarcane Mealybug
Family Pseudococcidae
Hosts (main). Sugarcane
(alternative). Sorghum, rice, and various grasses.
Damage This mealybug is usually situated on the stem beneath the sheath but is sometimes found on the stem just below ground level, on the root crowns, on the stem buds, and underneath the leaves. The leaves often turn red at the base as a result of the insects' presence. Sooty moulds often develop in severe infestations, and ants are associated.
Pest status The most important mealybug pest of sugarcane. It is often present in very large numbers, and the amount of honey-dew excreted considerable. It is probably toxicogenic; however, whether mealybugs really cause damage to sugarcane is debatable.
Life history Eggs are laid under the leaf sheath; each female lays up to 1000 eggs. Hatching takes only 10–14 hours, for the eggs are retained in the genital tract of the female until development is advanced.

First instar nymphs are quite active but generally only move from older to younger parts of the plant, or on to adjacent plants. Older nymphs are less active and move only reluctantly.

The adult male occurs both as apterous and winged forms, but is generally rare. Parthenogenesis is the normal mode of reproduction. The adult female is pinkish and is elongate-oval to round in shape, about 7 mm long, with well-developed anal lobes; legs rather short.

The life-cycle takes about 30 days to complete.
Distribution Widely distributed throughout the tropics. (CIE map no. A102).
Control Cultural methods are strongly advocated, including destruction of crop residues and trash; clean cultivation; and use of uninfested cane for planting.

Hot-water treatment can be effective.

Dipping of planting material into fungicidal solutions with added dieldrin appears to be a promising and convenient method of control, particularly since this routine involves stripping off the sheath.

Insecticidal application to standing cane is impracticable and usually unsuccessful.

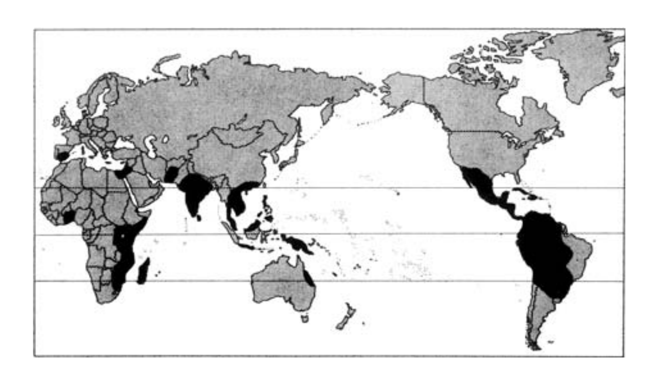
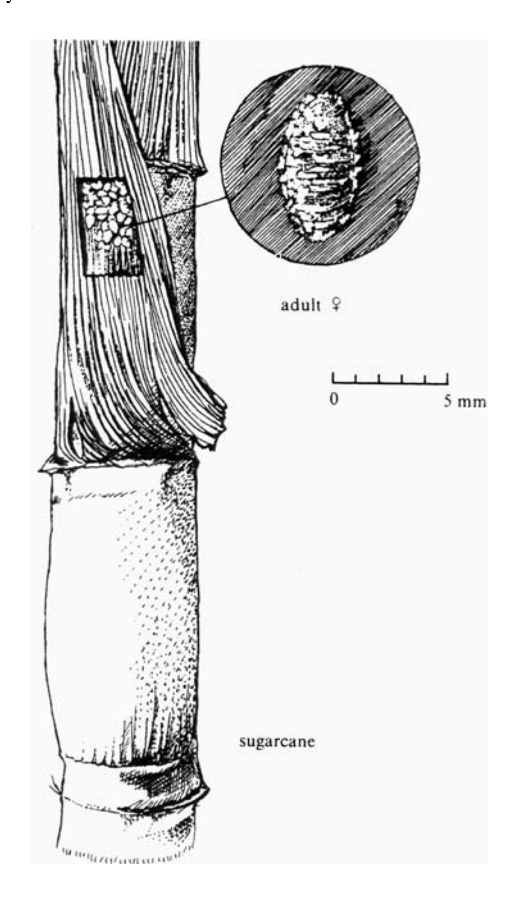


Fig. 9.98. Saccharicoccus sacchari (Pink Sugarcane Mealybug); Kenya.



Ceroplastes rubens Mask.

Common name Pink Waxy Scale
Family Coccidae
Hosts (main). *Citrus* spp.
(alternative). Coffee, tea, mango, fig, and various other fruit trees.
Damage Shoots, fruit stalks, and parts of the fruits may be covered with pink or reddish convex scales. Quantities of honey-dew are excreted and the scales are often found attended by ants. Often sooty moulds may be extensive where the honey-dew has dripped on to leaves and fruit.
Pest status Not an important pest usually but widespread and frequently found on many trees. On mango the fruits may fail to develop and fall prematurely.
Life history Life history details are not known, but may be expected to be similar to that of *Gascardia destructor*.

The adult female scale is covered by a pink waxy shell, often with white vertical stripes, and is 3–4 mm long, she lays 100s of eggs under the scale and then she dies.

Ants are usually found in attendance with the mature scales.
Distribution E. Africa, Seychelles, India, Sri Lanka, China, Japan, Malaysia, Philippines, Solomon Isles, E. Australia, Pacific islands, New Zealand and Hawaii (CIE map no. A118).
Control Control measures are seldom warranted against this pest, but if required the treatments suggested for *Gascardia destructor* should be effective.

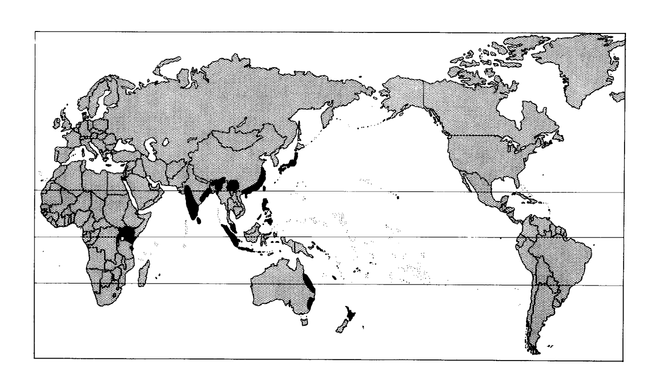
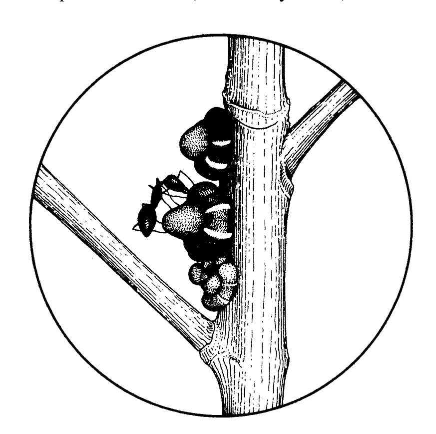


Fig. 9.99. Ceroplastes rubens (Pink Waxy Scale), S. China.



Chloropulvinaria psidii (Mask.)

(= *Pulvinaria psidii* Mask.)

Common name Guava Mealy Scale
Family Coccidae
Hosts (main). Guava
(alternative). Coffee, tea, *Citrus* spp., mango, and many other shrubs and trees, both crop plants and ornamentals.
Damage Young shoots and young leaves infested with oval green scales, sometimes causing leaf distortion and growth disturbance; often accompanied by sooty moulds.
Pest status A widespread and polyphagous species to be found on many different crops in many different parts of the tropics; not often serious but often part of a pest complex that requires controlling.
Life history The adult scales are shield-shaped, oval, rather convex, green in colour and about 3 mm in body length.

As with other scale insects the crawler (first instar nymph) is the active dispersive phase responsible for starting new infestations.

Eggs are laid beneath the body of the mature female in a conspicuous egg-sac, whereupon the female dies.

This scale is usually attended by ants for the honeydew excreted.
Distribution Widely distributed throughout the tropical regions of the world, but records rather sparse in some areas, and some records from temperate areas (CIE map no. A59).
Control See under *Coccus viridis* (page 213).

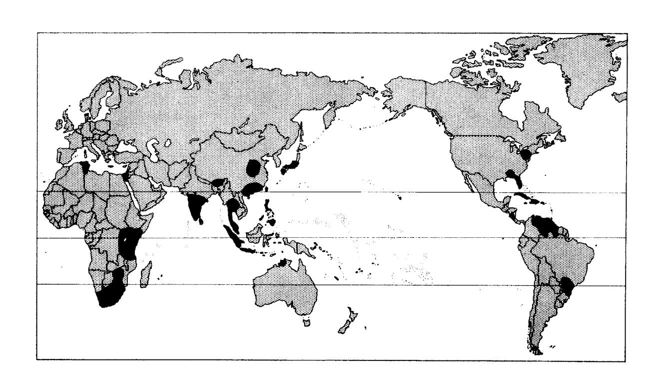
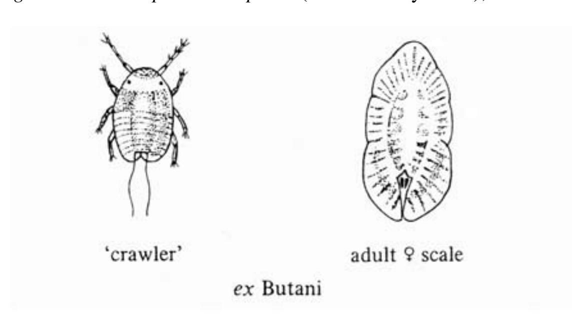
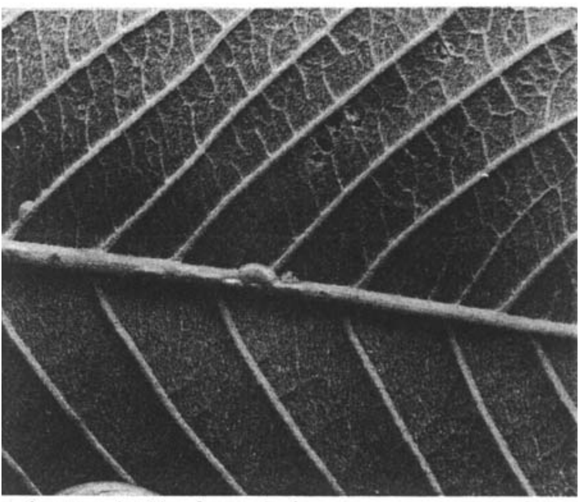


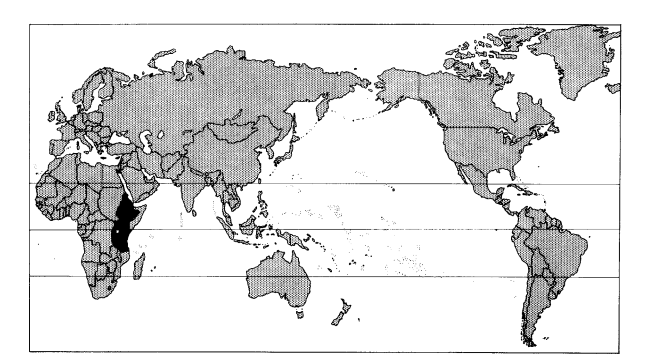
Fig. 9.100. Chloropulvinaria psidii (Guava Mealy Scale); S. China.





Coccus alpinus De Lotto

Common name Soft Green Scale
Family Coccidae
Hosts (main). Coffee, mostly *arabica*.
(alternative). A large number of wild and cultivated plants; important on *Citrus* spp. and guava.
Damage Rows of flat, oval, immobile green scale insects grouped especially along the main veins of the leaves and near the tips of green shoots. The upper surface of the leaves with honey-dew or with sooty moulds growing on the honey-dew.
Pest status A common but minor pest of mature *arabica* coffee; more serious on transplanted seedlings during their first two years in the field. Another Green Scale *C. viridulus* has been found on coffee in the Nandi hills of Kenya. Common on *Citrus* above about 1300 m where it replaces the lowland *C. viridis* in E. Africa.



Life history Eggs are laid below the body of the mature female scale.

When the scale hatches from the egg it is flat and oval, yellowish-green, and has six short legs. It takes up a position on a leaf or green shoot and begins to feed. It passes through three nymphal instars before becoming adult, each stage being larger and more convex than the preceding stage. Nymphs can change their position if conditions become unfavourable but the mature female is apparently fixed in position. The mature scale is 2–3 mm long.

Males have never been recorded; fertilization of the female either never occurs or else is of rare occurrence.

One generation takes less than two months.
Distribution A restricted species separated from *C. viridis* only in E. Africa, where it is found generally above about 1300 mm.
Control Control of this scale is best achieved indirectly by spray banding with dieldrin against the ants, as for *C. viridis*.

9.101. Coccus alpinus (Soft Green Scale); Seychelles.



Coccus alpinus on *Hibiscus* stems

Coccus viridis (Green)

Common name Soft Green Scale
Family Coccidae
Hosts (main). *Citrus* spp.
(alternative). A large number of wild and cultivated plants are attacked; coffee and guava are two important hosts.
Damage Rows of flat, oval, immobile green scales especially along the main leaf veins and near the tips of green shoots. Upper surfaces of leaves have spots of sticky transparent honey-dew or covered with sooty mould growing on the honey-dew.
Pest status A common, but usually minor pest of mature *Citrus*; more serious on young trees in the first two years after transplanting. *Coccus viridis* is generally found at low altitudes; above about 1300 m it is replaced by *C. alpinus* in E. Africa. Infestations are often found mixed with the Soft Brown Scale *C. hesperidum*, which has a similar life history and which can be controlled by the same sprays. This was a serious pest in Ceylon on coffee in about 1900, and was partly responsible for the changeover from Coffee growing to tea, in Ceylon.
Life history When the scale hatches from the egg it is flat and oval, yellowish-green, and has six short legs. It takes up a position on a leaf or green shoot and begins to feed. It passes through three nymphal instars before becoming adult, each stage being larger and more convex, but otherwise differing little from the preceding stage. Nymphs can change their position if conditions become unfavourable, but the mature female appears to be fixed in position. Mature scales are 2–3 mm long. Eggs are laid below the body of the mature female.

One generation takes 1–2 months.

Males have never been recorded; fertilization of the female must be a rare event, if indeed it ever occurs.
Distribution Cosmopolitan in the tropics with the exception of Australia (CIE map no. A305). In E. Africa it is only found up to a height of 1000–1300 m.
Control Banding the tree stump with dieldrin keeps off the attendant ants and allows the natural enemies to clean up the infestation; the band should be at least 15 cm wide, and care should be taken to avoid leaving any bridges. If the trees are too small for satisfactory banding the dieldrin mixture should be sprayed on to the collar of the tree and a small area of mulch round the collar.

In severe infestations, in addition to dieldrin banding, the tree foliage should be sprayed with diazinon, malathion, or dimethoate, as a full-cover spray using as high a nozzle pressure as possible. Do not use dimethoate on rough lemon trees or non-budded rough lemon stock.

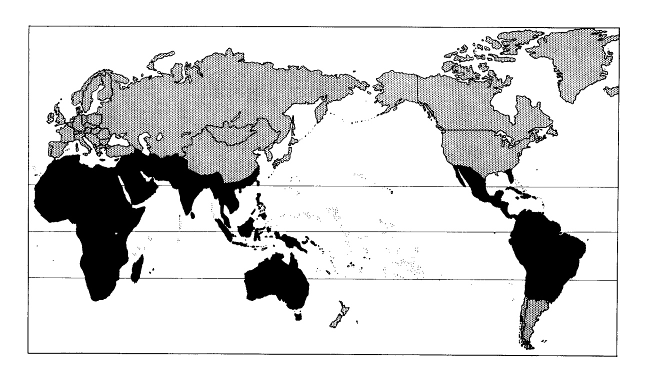
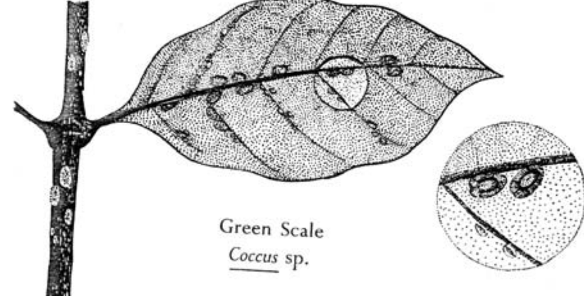


Fig. 9.102. Coccus viridis (Soft Green Scale); Kenya.



Gascardia brevicauda (Hall)
(= *Ceroplastes luteolus* De Lotto)

Common name White Waxy Scale
Family Coccidae
Hosts (main). Coffee, both *arabica* and *robusta*.
(alternative). *Citrus* spp.
Damage White immobile insects like blobs of cream found on green shoots and leaves. The white material is a soft wax which is easily rubbed off to reveal the shiny brown carapace of the scale.
Pest status A minor pest of both *arabica* and *robusta* coffee; sporadically severe attacks occur, especially at lower altitudes. This scale, is however, a very slow feeder and enormous numbers must be present before the coffee bush is perceptibly damaged.
Life history Eggs are laid under the carapace of the mature female scale which remains attached to the plant even after the eggs have hatched.

When the young nymphs hatch from the eggs they are flat and oval, purplish-brown and have six short legs. The nymphs take up positions on a leaf, usually on the upper surface and next to a main vein; here they begin to feed. A waxy plate develops on the back and a waxy fringe round the edge of the body. Later the wax covers the whole body and forms a star shape. Each scale next moves off the leaves and takes up a new position on a green shoot. Here it passes through a conical stage before assuming the more rounded form of the mature female scale. Mature scales are about 6 mm in diameter.

Males have never been recorded.

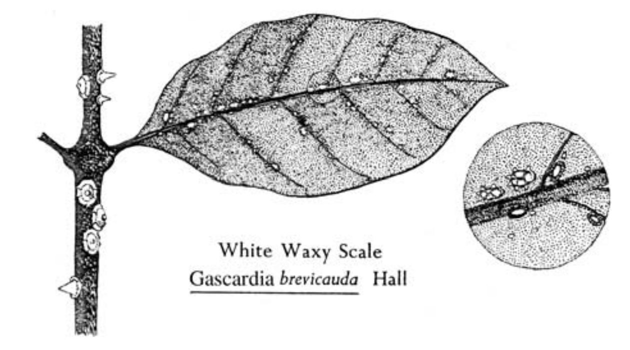
The complete life-cycle takes about six months, the majority of scales maturing and laying their eggs during the main rainy season.
Distribution Recorded only from Africa; in Angola, Kenya and Uganda.
Control In a minor outbreak, badly infested branches should be cut off and left on the ground for the parasites to emerge.

Sprays have little or no effect on the older stages found on the green shoots. These stages are well protected by their waxy covering. Control measures should therefore be directed against the young stages found on the leaves. Spray to run off with an emulsion of white oil in water. The best time for spraying is usually one or two months after the end of the rainy season. Even after their death there is little change in the appearance of the young scales. Development, however, stops and there is no migration from leaves to shoots.

If ants are in attendance a dieldrin band should be applied to the trunk of the tree, at least 15 cm wide, taking care to ensure that no bridges are left.

For extra effectiveness the following insecticides can be added to the white oil: carbaryl, dimethoate, malathion, azinphos-methyl, and carbo-phenothion.

Fig. 9.103.



Gascardia destructor (Newst.)

(= *Ceroplastes destructor* Newst.)

Common name White Waxy Scale
Family Coccidae
Hosts (main). *Citrus* spp.

(alternative). Coffee, various fruit trees (guava, persimmon) shade trees and shrubs (gardenia).

Damage The large white waxy scales encrust the twigs and leaves of the host trees; often accompanied by sooty moulds and ants feeding on the honey-dew excreted.

Pest status A common pest of *Citrus* spp. and often found on coffee; only occasionally is it a serious pest.

Life history Typically there is only one generation per year.

The 'crawlers' (first stage nymphs) emerge from the eggs under the female scale, and eventually settle along the veins of the leaves. After five or six weeks they crawl back on to the twigs and settle permanently in position. They start secreting their wax cover as they grow in size, and gradually mature.

After about ten months the mature females lay eggs.

If the wax covering is removed the soft reddish female scale is revealed.

Distribution W., E. and southern Africa, Madagascar, Papua New Guinea, Australia, New Zealand, Florida and Mexico (CIE map no. A117).

Control Spraying with white oil, either alone or in combination with carbaryl, dimethoate, malathion, azinphos-methyl, or carbophenothion, while the crawlers are still on the leaves and before migration back to the twigs commences.

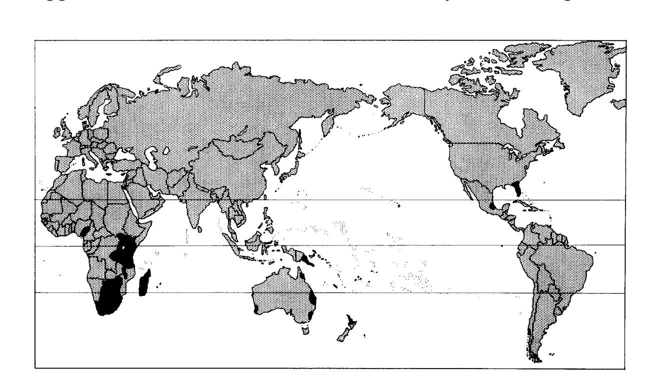
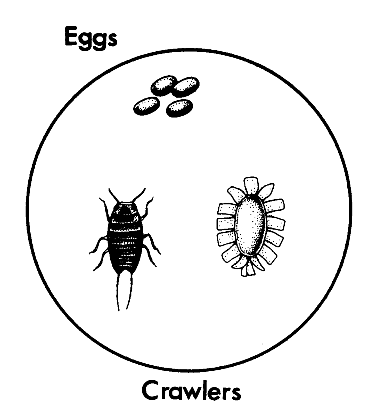
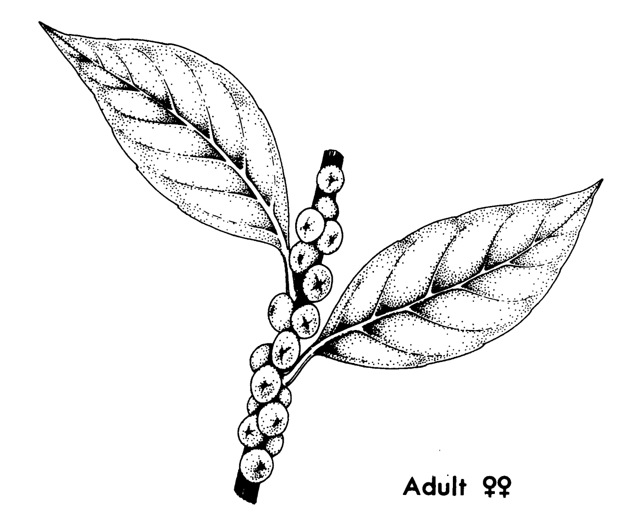


Fig. 9.104.

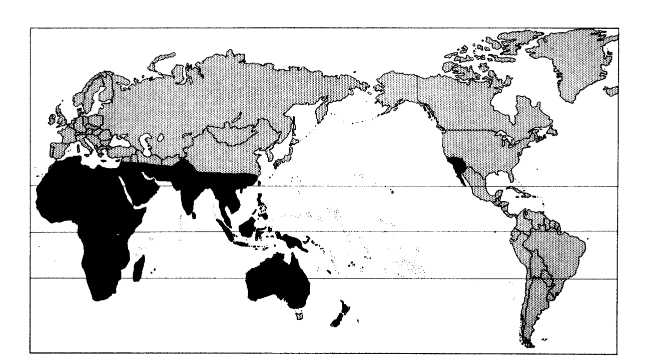




Parasaissetia nigra (Neitn.)

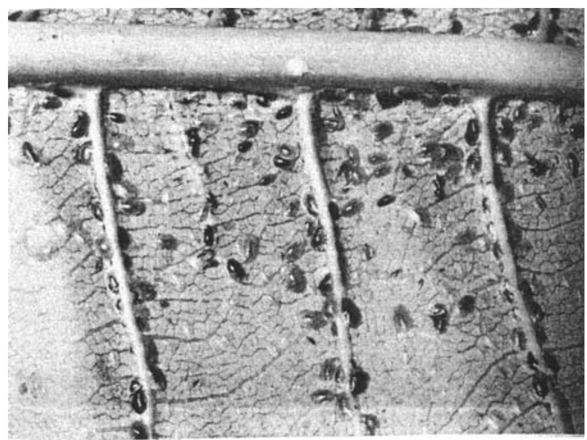
(= *Saissetia nigra* Neitn.)

Common name Nigra Scale
Family Coccidae
Hosts A polyphagous species found on *Citrus* spp., rubber, kola nut, and other crops, as well as ornamentals such as frangipani.
Damage Oval dark scales clustered on twigs, shoots and leaves, sometimes causing leaf distortion, and often associated with sooty moulds. Citrus fruits often covered with mould.
Pest status Usually not a serious pest, more often part of the *Citrus* pest complex which will require overall control treatment. The infestation found on frangipani in the Seychelles was very heavy and the undersurface of almost all the leaves of several adjacent trees were covered with scales, most lying alongside veins.

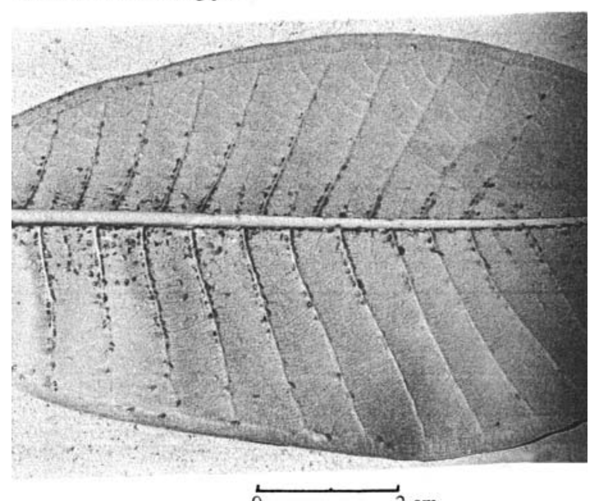


Life history The adult scales are oval and convex in shape, measuring some 2–3 mm in length and 1.5–2 mm in breadth. Young scales are generally paler, but the adults are dark brown or occasionally black in colour, although coloration does tend to be a variable character. The female scales reproduce parthenogenetically and lay eggs under the scale.
Distribution Widely distributed throughout Africa, India, S.E. Asia up to S. China and Taiwan, Philippines, Indonesia, Australasia and New Zealand, and in California, USA.
Control As with other scales natural parasitism and predation usually controls population numbers most of the time, but occassionally pesticides have to be used, when the usual chemicals effective against scales may be employed. The adult scale is very difficult to kill and most spray programmes rely on killing the young nymphs, and to this effect repeated sprays at one to two week intervals are generally required.

Fig. 9.105. Parasaissetia nigra (Nigra Scale) on frangipani leaf; S. China.



infested leaf of frangipani



Saissetia coffeae (Wlk.)
(= *S. hemisphaerica* T.-T.)

Common name Helmet Scale (= Hemispherical Scale)
Family Coccidae
Hosts (main). Coffee, both *arabica* and *robusta*.

(alternative). A wide range of alternative hosts including tea, *Citrus*, guava, mango and many other plants both wild and cultivated. Auocado Rubber Fig.

Damage Immobile insects, green when young but dark brown when older, clustered on the shoots, leaves and green berries. They are often arranged in an irregular line near the edge of a leaf blade, or along the midrib.

Pest status A minor pest of *arabica* and *robusta* coffee; very occasional severe outbreaks have been recorded especially on rather unhealthy bushes. A small form of this species is found on coffee roots in the Kissi highlands of Kenya.

Life history Eggs are laid beneath the carapace of the mature female scale which remains attached to the plant even after the eggs have hatched; one female may lay several hundred eggs (up to 600).

When the scale hatches from the egg it is flat and oval, greenish-brown, and has six short legs. It takes up a position on a leaf, berry or green shoot and begins to feed. It passes through three instars before becoming adult. The immature females, which can move short distances if conditions become adverse, have an H-shaped yellow mark on their body. This is diagnostic of the species. Adult females have a strongly convex helmet-shaped carapace and are dark brown; this stage is immobile. Mature scales are about 2 mm long.

Males have never been recorded; and it is presumed that reproduction is always by parthenogenesis.

One complete generation appears to take about six months in the field.

Distribution Almost completely cosmopolitan; widespread through the tropics and in some subtropical areas, occurring as far north as Spain and Turkey, and California (CIE map no. A318).

Control Ensure that infested trees receive optimum quantities of mulch and fertilizer. Cut off heavily infested branches and leave on the ground for the parasites to emerge.

White oil as a drenching spray is effective against the young scales, but has negligible effect on the adult females. A second spray will be required after about 3–4 weeks.

If ants are in attendance then a dieldrin band should be sprayed around the base of the trunk.

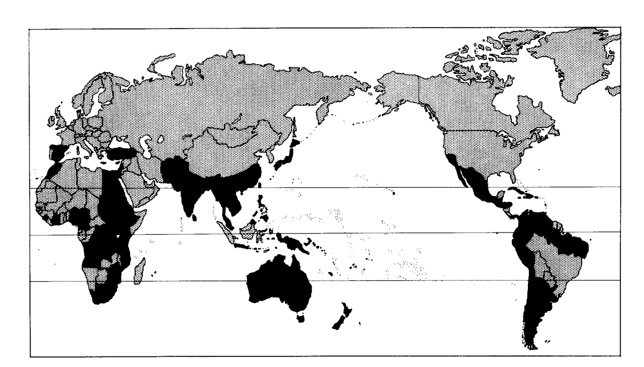
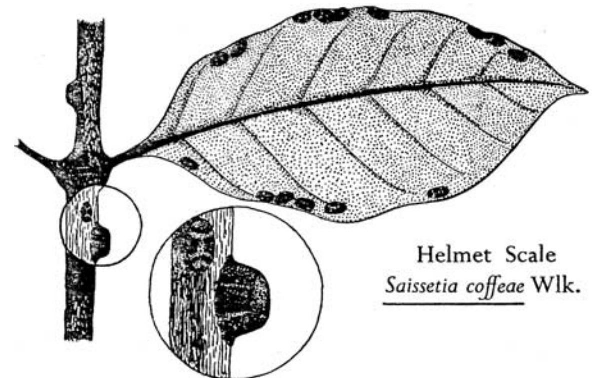


Fig. 9.106. Saissetia coffeae (Helmet Scale); Kenya.



Adult scales on unknown leaf; Sarawak



Saissetia oleae (Bern.)

Common name Black Scale (Olive Scale)
Family Coccidae
Hosts (main). Olive, *Citrus* spp.
(alternative). A very wide range of trees.
Damage The presence of conspicuous blackish scales on the twigs and shoots. In heavy infestations the shoots and leaves wither and fade, and there are often heavy coatings of sooty moulds; development of leaves and fruit may be impaired.
Pest status A polyphagous pest recorded from many host plants, and very widely distributed throughout the world.
Life history A single female lays 1000–4000 eggs (average about 2000); the egg-laying period lasts 2–4 weeks. The eggs are white, turning brown; wax flakes are deposited between the eggs to prevent them sticking together. Hatching takes 15–20 days.

The crawlers start feeding within a few hours. The nymphs tend to prefer feeding on the shoot tips and the undersides of the leaves, but the adults prefer the shoots and twigs. Nymphal development takes about 2–3 months; however, if conditions become unfavourable the nymphs may go into diapause during which they are very difficult to kill.

Winged males are only occasionally found; reproduction usually occurs without fertilization.

Under suitable climatic conditions the life-cycle takes about 3–4 months.
Distribution Almost cosmopolitan in distribution, but not recorded from W. Africa; northernmost records from Japan and southern France (CIE map no. A24).
Control Control recommendations are most effective when directed against the nymphal stages. The adult female scale is particularly difficult to kill with contact insecticides, but the nymphs are more susceptible.

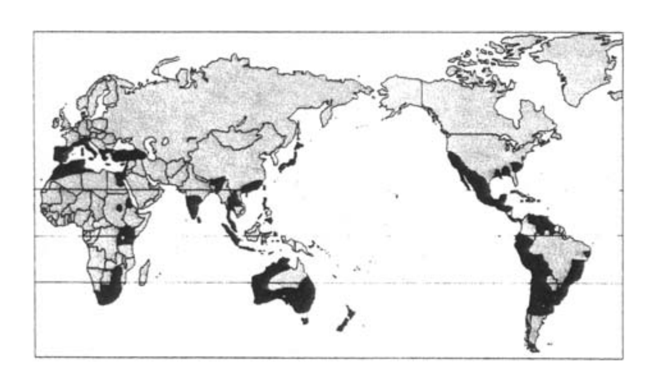
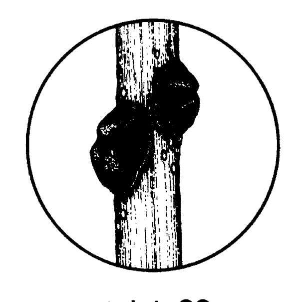
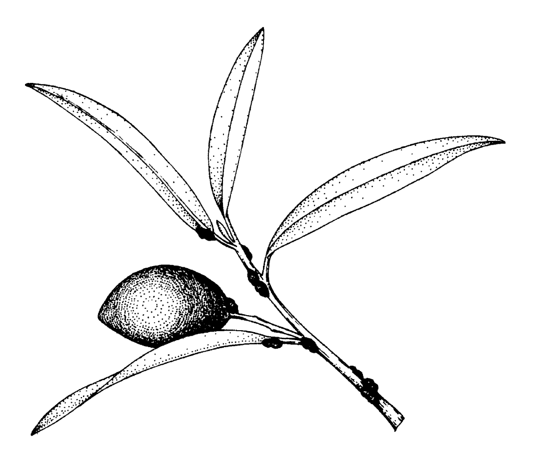


Fig. 9.107. Saissetia oleae (Black/Olive Scale); S. China.





Asterolecanium coffeae Newstead

Common name Star Scale (Coffee Pit Scale)
Family Asterolecaniidae
Hosts (main). Coffee, usually *arabica*.
(alternative). Jacaranda and loquat trees.
Damage Green branches are sharply elbowed at the nodes with pits in the green bark on the inside of the bends. Affected nodes often bear drooping, dead leaves. Internodes beyond the elbow bends are often elongated producing whip-like branches. Numerous small red or yellow scales are usually visible in bark crevices, especially near ground level.
Pest status A sporadically serious pest of *arabica* coffee grown below 1700 m.
Life history When egg-laying is completed there are some 50 eggs under the carapace and they fill it completely. After hatching the crawlers leave the carapace through a small orifice at the hind end. Empty carapaces remain on the tree for many months; they are then greenish-grey and easily distinguished from those containing living females or eggs. The crawlers are flat and oval, yellow, and just visible to the unaided eye.

The immature females are reddish-brown and have coarse hair-like projections, especially at the edge of the body where they form a fringe.

Mature females are covered with a hard but transparent scale; as the eggs are laid at one end of the carapace, so the body of the female progressively shrinks to make room for them. Most eggs are laid during rainy seasons.

Development takes about six months.
Distribution E. Africa, Angola, and Zaïre.
Control Infested trees should be pruned severely and most of the crop stripped off.

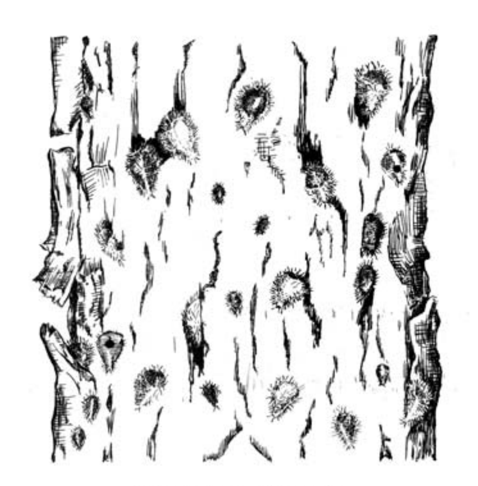
Optimum quantities of nitrogen and mulch should be applied to infested trees. Paint as much as possible of the infested brown bark with tar oil; keep the brush very wet, allowing plenty of the mixture to soak into the crevices.

If a good kill of bark-feeding scales is obtained, experience has shown that (in the absence of road dust) parasites and predators can be relied on to kill the scales feeding on green branches. If carefully applied, only one tar oil treatment is usually required.

Recommended insecticides are: azinphos-methyl, diazinon, malathion, parathion, parathion-methyl, and petroleum (white) oil.

Fig. 9.108. Asterolecanium coffee (Coffee Pit Scale); Kenya.





Aonidiella aurantii (Maskell)

Common name California Red Scale
Family Diaspididae
Hosts (main). *Citrus* spp.
(alternative). A wide range of fruit trees, and shrubs, notably roses.
Damage Infestation is indicated by the presence of numerous small circular reddish-brown scales on the trunk, branches, leaves and fruit. Severe infestations may result in branch die-back. When on a leaf the scale is often surrounded by a small pale chlorotic spot.
Pest status A major pest of *Citrus* in E. Africa, and in many other *Citrus*-growing areas.
Life history After copulation with the winged male, the female scale produces living young ('crawlers') at the rate of about 2–3 per day. These may shelter beneath the carapace for a short period before walking away and finding a suitable feeding site in a depression or crevice. After settling down, they do not normally move again. The developing scale moults twice before becoming an adult female. The immature males, like the females, are scale-like and reddish-brown but their bodies are elongate and they only reach about a quarter of the size of an adult female.

The adult male is a fragile two-winged insect with long filamentous antennae. The body of the female is flattened, crescent-shaped and reddish-brown, and it is covered with a circular, transparent, waxy carapace, 1.5–2.0 mm in diameter, through which the body can be seen.
Distribution Cosmopolitan throughout the tropics and subtropics, but with no records from W. Africa (CIE map no. A2).
Control If high-quality fruit are being produced trees should be sprayed when 25% of the fruits are infested with one or more Red Scales. Recommended sprays are either diazinon or malathion in water with added white oil, as a full-cover spray using as high a nozzle pressure as possible. A repeat spray should be made after 2–3 weeks.

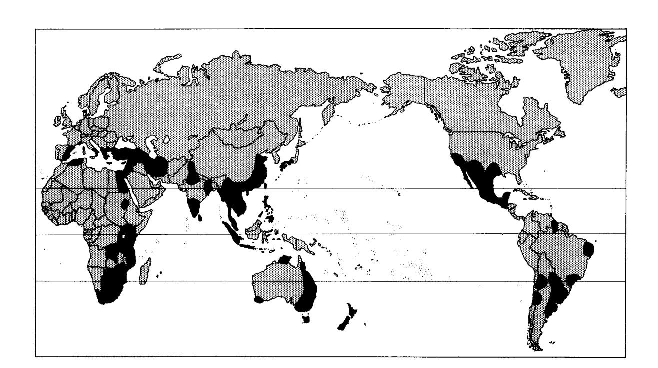
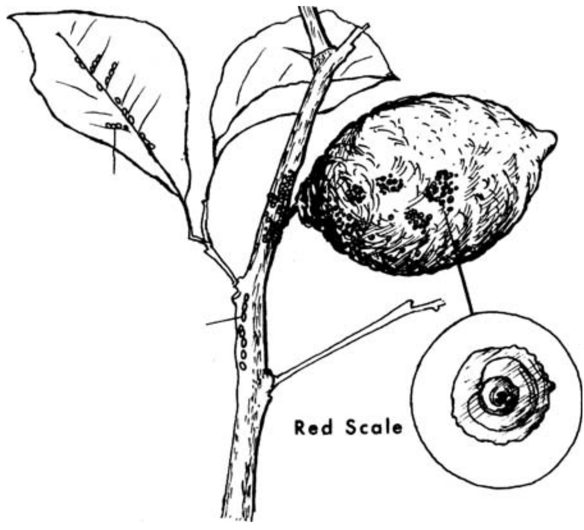
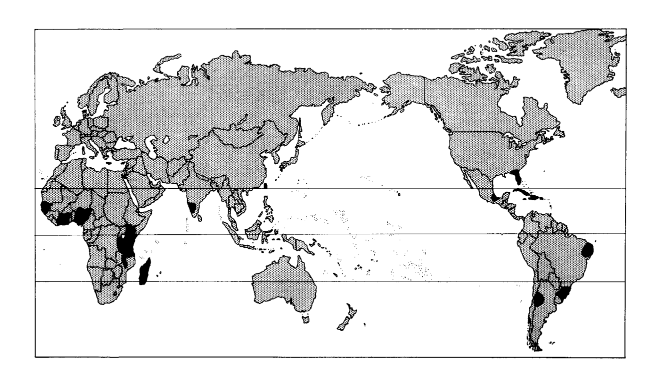


Fig. 9.109. Aonidiella aurantii (California Red Scale) on lemon in Kenya, and orange in Ethiopia.



Aonidomytilus albus (Ckll.)

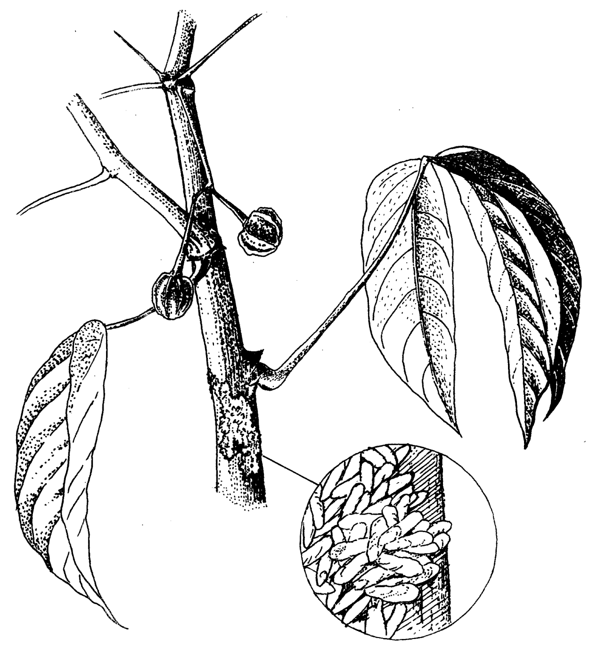
Common name Cassava Scale
Family Diaspididae
Hosts (main). Cassava (*Manihot* spp.)
(alternative). Various species of *Solanum*, and other plants.
Damage The trunk and petioles are covered with mussel-shaped white scales. When young plants are attacked the leaves turn pale, wilt and fall, and root development may be impaired.



Pest status Not usually a serious pest, but of some importance locally in E. Africa.
Life history The females are silvery-white, mussel-shaped scales, 2.0–2.5 mm long. The brown, oval exuvium is at the anterior end of the scale. The female insect under the scale is oval, and reddish.

The male scale is much smaller and oval, about 1.0 mm long.
Distribution W. and E. Africa, Madagascar, India, Taiwan, Florida, Mexico, W. Indies, Argentina and Brazil (CIE map no. A81).
Control Control measures are not usually required.

Fig. 9.110. Aonidomytilus albus (Cassava Scale); Kenya.



Aspidiotus destructor Sign.

Common name Coconut Scale (Transparent Scale)
Family Diaspididae
Hosts (main). Coconut

(alternative). Other palms, mango, bananas, avocado, cocoa, *Citrus*, ginger, guava, *Artocarpus,* capsicums, *Pandanus*, papaya, rubber, sugarcane, yam, etc.

Damage A severe infestation forms a continuous crust over the undersurface of all leaves. The leaves first become yellow, because of sap loss and blocking of the stomata, and eventually die. The flower spikes and young nuts are also likely to be infested. Infestation is most severe in areas where rainfall is high and the palms are planted close together; neglected plantations are particularly susceptible. Infestations are usually attended by ants which feed on the honey-dew excreted by the scales; the ants usually nest in the palm crowns.

Pest status One of the most serious pests of coconut, and other crops. Dispersal of this scale has been shown to be effected by both birds and bats.

Life history The body of the adult female is bright yellow and nearly circular in outline, and is covered with a flimsy, semitransparent, only slightly convex scale. The scale diameter is 1.5–2.0 mm. The male scale is much smaller, oval in outline, and the insect body is reddish; on attaining maturity the male insect has a pair of wings, is motile, and leaves the scale.

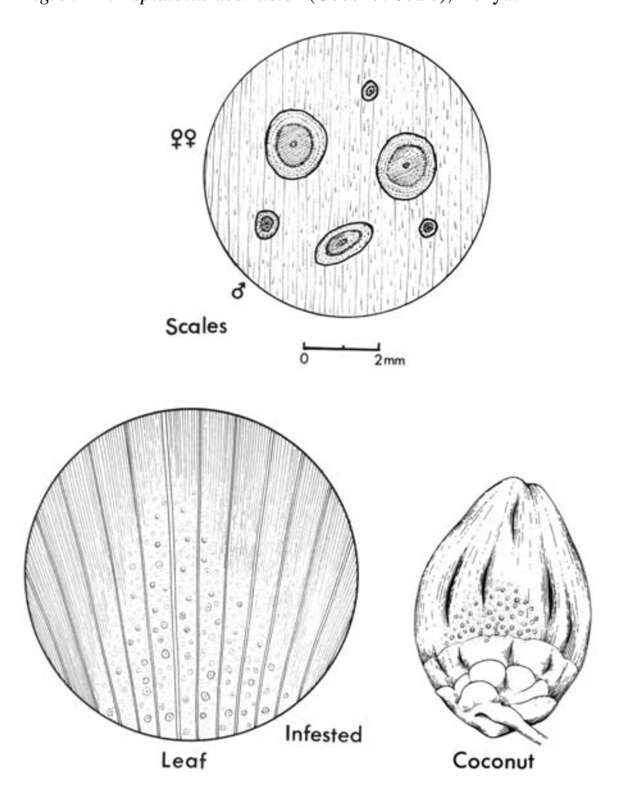
The eggs are yellow, tiny, and are laid under the scale around the body of the female. Incubation takes 7–8 days. On hatching, the crawler leaves the maternal scale and takes up a position on the leaf and starts feeding. The nymph remains on this site throughout its nymphal life, and if it is a female it also stays there throughout its adult life. The male nymph moults three times, and the female twice. Larval development takes 24 days in the male, and longer in the female.

The life-cycle takes 31–35 days; and there are about ten generations per year.

Distribution Pantropical; occurring up to Iran, Japan, and California, and southwards down to S. Africa and Australia (CIE map no. A218).

Control The waxy scale covering the insect makes control by insecticides difficult. Successful insecticides have been parathion, malathion and dieldrin.

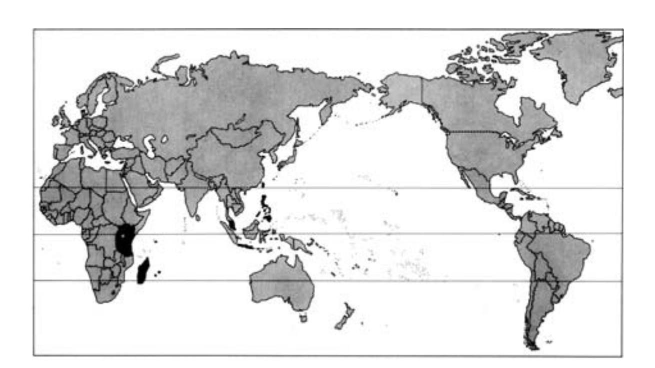
Fig. 9.111. Aspidiotus destructor (Coconut Scale); Kenya.



Aulacaspis tegalensis (Zehn.)

Common name Sugarcane Scale
Family Diaspididae
Hosts (main). Sugarcane
(alternative). The wild grass *Erianthus* sp. in Java which is only doubtfully separable from *Saccharum*.
Damage Essentially a stem-inhabiting pest, but does occur on leaves, although this may be considered as secondary and a result of crowding on the stem. Usually the bulk of the infestation is found under the leaf sheath, the looser the sheath the greater the scale population. The feeding of the scales on the leaves results in chlorotic spots which are drawn out along the length of the leaf.
Pest status A serious pest of sugarcane causing appreciable loss in yield (both of canes and sugar content) and making extensive replanting necessary. The crawlers can be dispersed for considerable distances by wind or movement of vegetation by field workers and transport. Greathead (1972) found that crawlers were carried up to 1000 m on quite low wind speeds.
Life history The normal post-embryonic development of Diaspididae consists of two instars in the female and four in the male; sexual dimorphism becoming apparent after the first nymphal moult.

The eggs are spindle-shaped, about 250 μm by 100 μm, yellow, and covered with powdery wax, and are laid under the female's scale; each female lays 500–1000 eggs (average 750).



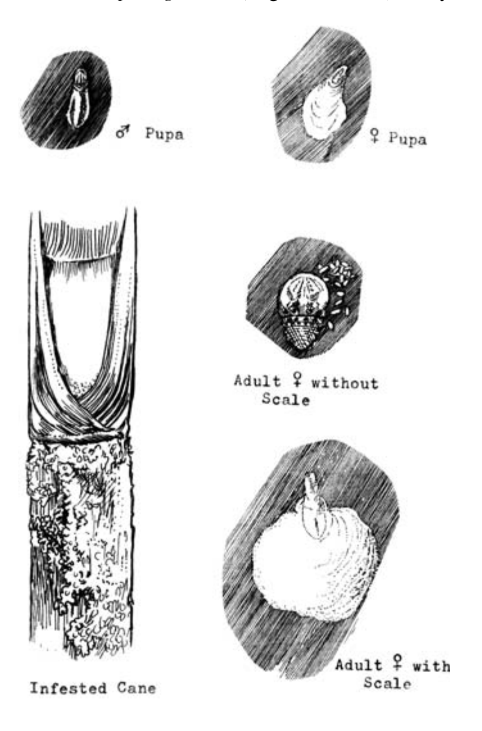
The first instar (crawler) is tiny, whitish, and with two long terminal setae. After a period of wandering it selects a feeding site, inserts its stylet into the plant, then becomes inert and starts to secrete wax. The secretions do not form a definite scale during the first instar, as happens in certain other Diaspididae. Legs and antennae are lost during the first moult, and after this the sexes acquire different body forms. The second instar female assumes the pear-shaped form of the adult female, and the second instar male is more elongate with the anterior end narrowest.

Males are always present and mating takes place immediately after the final moult.

The life-cycle takes about 26–60 days according to temperature (and altitude) and in Mauritius there are eight generations per year.
Distribution E. Africa, Madagascar, Mauritius, Seychelles, Malaya, Java, Philippines, and Taiwan (CIE map no. A187).
Control Use of clean planting material, by washing or hot-water treatment to kill the scales and field hygiene, and varying the date of harvest, is recommended. There is scope for practical biological control of this pest using parasitic Hymenoptera and various predators.

If pesticides have to be employed the following chemicals should be effective: white oil (petroleum oil) or malathion plus white oil, either as a dip for planting material or as a spray for the setts. Various organophosphorous compounds used alone are effective against crawlers but not against eggs and most of the fixed stages of the scale.

Fig. 9.112. Aulacaspis tegalensis (Sugarcane Scale); Kenya.



Control of Armoured Scales (Homoptera; Diaspidiae)

Most Diaspididae are more or less invulnerable as adults by virtue of their thick, waxy, immobile protective 'scale'. Eggs are often laid under the scale of the gravid female who gradually dies as oviposition proceeds. The young 'crawlers' emerge from the shelter of the maternal scale and find new locations on which to settle. Young scales often settle on leaves and fruits initially (presumably they are more nutritious), which of course are deciduous, and then when older move to permanent locations on twigs. They are only mobile during the first few instars, the crawler being the dispersive stage; the mature nymphs pupae and adult females are all permanently fixed to the plant tissues by the stylet embedded into the host vascular system.

The adults are slightly susceptible to some systemic insecticides, but generally little control has been achieved in this manner. Thus the only stages vulnerable to contact pesticides are the crawlers and young nymphs. Generally, armoured scales are very difficult to kill with pesticides, but at the same time they are usually heavily parasitized by chalcidoid wasps; too often the typical result of pesticide application has been a poor kill of scales but extensive destruction of natural enemies, and often a pest population resurgence. In some situations now it is quite certain that any application of DDT to a citrus orchard will result in a scale population outbreak! Present practice is to use chemicals only as a last resort. The range of approaches to scale population control include:

(1) Cultural control
(a) Phytosanitation – heavily infested sugarcane plants should be rogued and burned, if economically feasible; heavily infested fruit trees are usually best left for the parasites to emerge.
(b) Clean planting material – use of clean planting material will delay any scale population build-up. Cleaning can be done with use of oils, hot water or by washing, and also by fumigation.
(2) Biological control
(a) Natural control – allowing alternate trees, or alternate tree rows, to remain unsprayed on alternate years, to permit parasite populations to survive and to build-up.
(b) Biological control – the supplementation of natural control by filling in gaps in the natural enemy spectrum with imported species of predators and/or parasites.
(3) Pesticides
(a) Dips and/or winter washes with tar oils, for use on deciduous trees, against overwintering scales and eggs.
(b) Sprays of petroleum or white oils against young nymphs, but care is required as these oils are basically phytotoxic.
(c) Systemic insecticides, such as dimethoate; but generally the level of control is poor.
(d) Contact insecticides, against young nymphs, such as diazinon, ethion, malathion, parathion and carbaryl; these sprays are usually more effective if mixed with white oil.

These pesticide treatments are highly destructive to the natural enemies, they show high mammalian toxicity, and may also be phytotoxic at times. Hence their use should be avoided if possible, and reliance placed on the long-term effect of natural enemies. The use of winter washes of tar oils is recommended, but is only applicable to deciduous trees in cooler regions.

Chrysomphalus aonidum (L.)

(= *C. ficus* Ashm.)

Common name Purple Scale (Florida Red Scale)
Family Diaspididae
Hosts (main). *Citrus* spp.
(alternative). Coconut, date palm, mango, tea, cinnamon, and a wide range of mono- and dicotyledons.
Damage This scale usually occurs on fruits and leaves, but is occasionally found on green shoots and twigs. The saliva is apparently toxic and produces damage and necrosis of the host plant tissues.
Pest status A serious pest of *Citrus*, and also widespread on many other crops and plants. This scale originates from the W. Indies but now is widespread throughout the tropics and subtropics, but has a preference for more humid climates. Common in greenhouses in temperate climates.
Life history Eggs are laid under the scale of the female insect. The crawlers emerge within a few hours; they are easily dispersed by wind, insects and cultivation practices. The young scales are found mainly along the midribs and veins of leaves, or in depressions in the fruit. After settling the nymphs start secreting the characteristic waxy carapace or scale.

The adult female scale is purplish and circular, with a reddish-brown 'boss' or 'nipple' in the centre. Parthenogenesis does not appear to be of significance in the life-cycle of this species.

The winged adult males are very short-lived and do not feed.
Distribution Cosmopolitan in the tropics and subtropics, but no records from W. Africa. Known as the Florida Red Scale in America (CIE map no. A4).
Control The usual range of insecticides recommended for use against diaspid scales is as follows: diazinon or malathion, preferably with added white oil, and carbaryl and parathion.

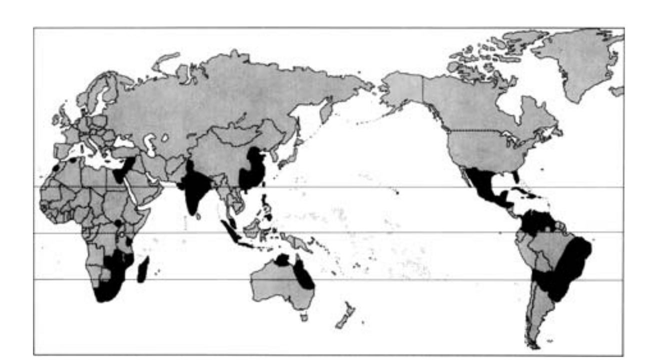


Fig. 9.113. (a). *Chrysomphalus aonidum* (Purple Scale), *Kenya.*

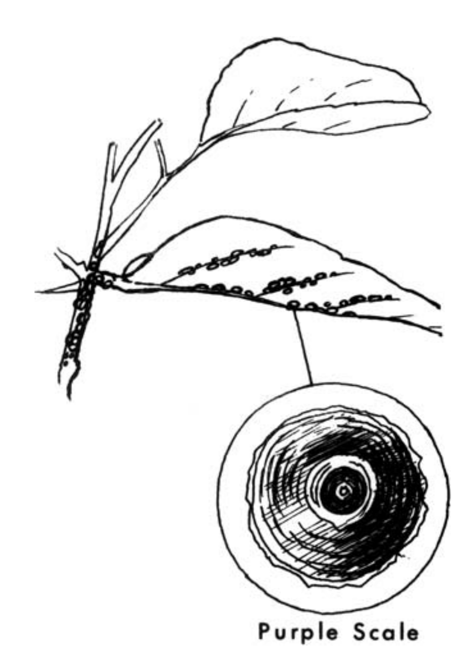
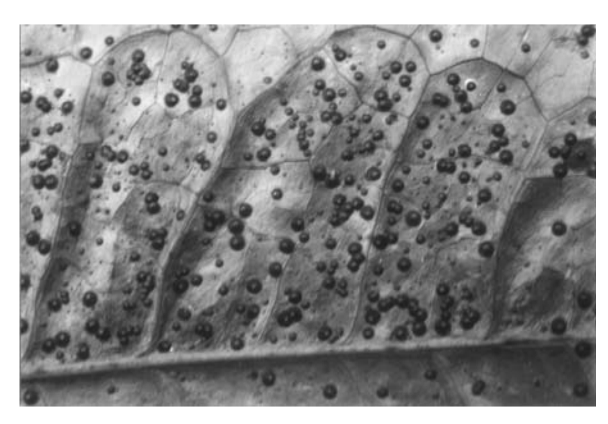


Fig. 9.113. (b) Scales on leaf of tea, Malawi.



Ischnaspis longirostris (Sign.)

Common name Black Line Scale (Black Thread Scale)
Family Diaspididae
Hosts (main). Coffee and coconut.
(alternative). *Citrus*, bananas, oil palm, mango, *Annona*, and other plants.
Damage Leaves, shoots, and fruit can be encrusted with this scale which often occurs in very large numbers. The leaves become mottled with discoloured patches and they curl downwards. Growth of shoots can be inhibited, and yield reduced in severe cases.
Pest status Not a serious pest usually, but very widespread throughout the tropics and common on many crops. Particularly harmful to coconut in the Seychelles.
Life history The female scale is long and slender, black and shiny, slightly wider posteriorly. The shed skin of the first instar nymph remains conspicuously attached to the scale at the anterior end. The length of the scale is 3–4 mm. The eggs are yellow.
Distribution Probably almost completely pantropical in distribution, but records at present are from Egypt, W., E. and S. Africa, Madagascar, Sri Lanka, Malaya, Java, Papua New Guinea, West Irian, N. Australia, Hawaii, and various Pacific islands, S. USA (Florida), W. Indies, and C. and S. America (CIE map no. A235).
Control In the Seychelles coccinellid beetles of the genera *Chilochorus* and *Exochomus* imported from E. Africa have to some extent controlled this pest.

Insecticides are not generally required, but according to Wyniger (1968) sprays of white oil, diazinon, ethion, or parathion, are effective if applied twice at a two-week interval.

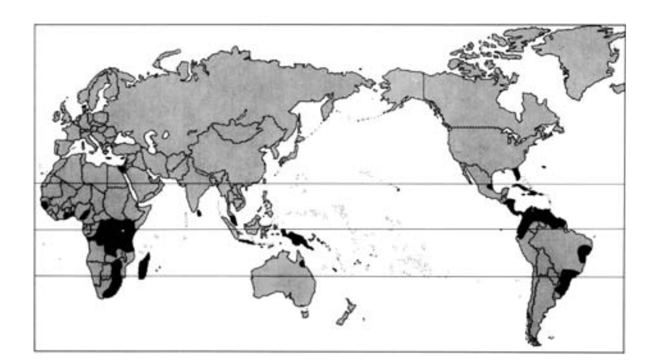
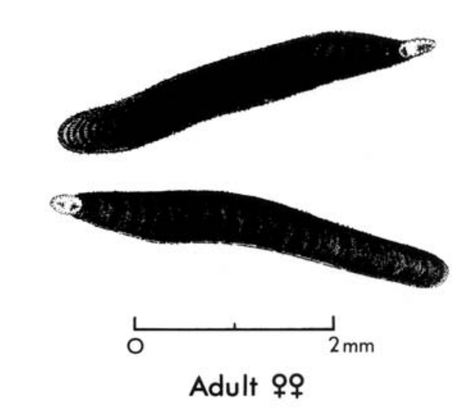
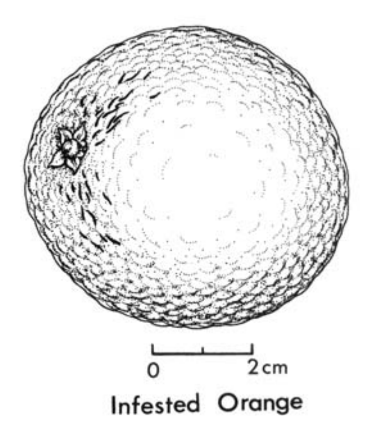


Fig. 9.114. Ischnaspis longirostris (Black Line Scale); Kenya.





Lepidosaphes beckii (Newman)

Common name Citrus Mussel Scale (Purple Scale)
Family Diaspididae
Hosts (main). *Citrus* spp., particularly severe on orange.
(alternative). All *Citrus* spp., and also on *Croton* spp. and a few other shrubs.
Damage Numerous small, purplish-brown, mussel-shaped objects on the leaves, fruits and branches. Premature leaf-fall and die-back of branches may follow a severe outbreak. Very heavy infestations on branches may pass unnoticed owing to the colour of the scales.
Pest status A serious pest of *Citrus* in many parts of the world. Probably introduced into E. Africa on infested nursery stock.
Life history After copulation with the winged male, the female lays 50–100 eggs and they are deposited under the narrow tapering part of the carapace. The body of the female scale contracts into the broader part of the carapace as the eggs are laid down.

After the young scales ('crawlers') hatch from the eggs they walk out from under the carapace and, having selected a suitable site on leaves, fruits or stems, settle down and begin to feed. They do not move again but with each successive moult gradually change from the oval form of the crawler to the mussel shape of the adult.

The carapace of the adult female is purple-brown, and it is the shape of a mussel shell. It is about 2 mm long and 0.6 mm broad at the widest part.

Male crawlers settle down in the same way as the females and develop the same mussel shape. When about 1 mm long, growth of the carapace stops, and after a resting period the fragile, winged male emerges from under it and flies off the find a female to fertilize.

The total life-cycle probably takes 2–4 months according to temperature.
Distribution Indigenous to the Orient, but now cosmopolitan throughout the tropics and subtropics (CIE map no. A49).
Control The recommended insecticides are diazinon, malathion and carbaryl, to be sprayed on the trees; the first two are more effective if white oil is added to the spray.

Carbaryl is more persistent and only one spray is usually required, but two sprays of the others are necessary at an interval of 3–4 weeks.

Care should be taken not to upset the (fortuitous) natural control exerted by the specific parasite *Aphytis lepidosaphes* now present in most *Citrus* growing areas.

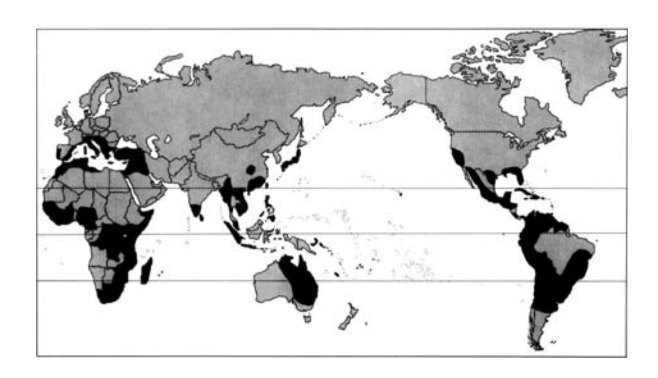
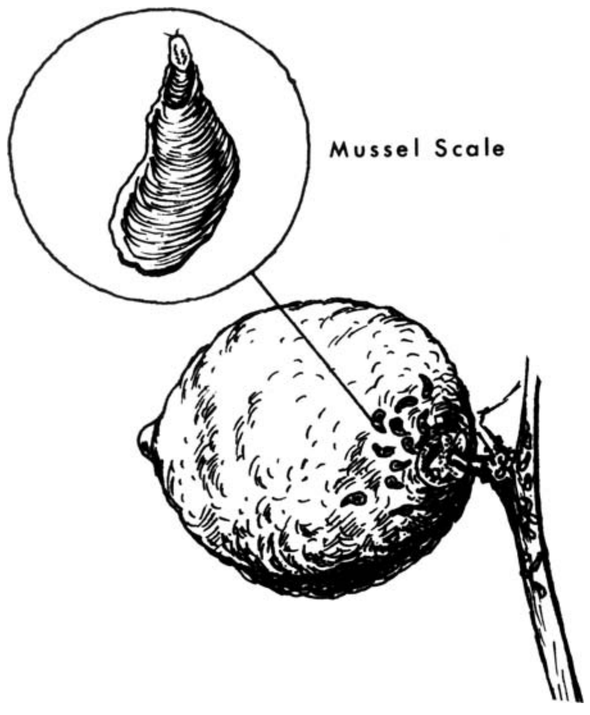


Fig. 9.115. Lepidosaphes beckii (Citrus Mussel Scale); Kenya.



Phenacaspis cockerelli (Cooley)

Common name Mango Scale (Oleander Scale)
Family Diaspididae
Hosts (main). Mango
(alternative). Coconut, oil palm, and oleander.
Damage Upper surface of leaves are encrusted with small rounded white scales; in heavy infestations leaves may be affected, and palm fruits are sometimes shrivelled when covered with scales.
Pest status Usually a minor pest on the crops listed above; only occasionally does it appear to cause sufficient damage for concern.
Life history The adult scale is rounded or slightly elongate, usually about 2–3 mm in length, and with the nymphal exuvium conspicuously dark brown at the pointed end while the rest of the scale is white.

As with many other hard scale infestations the scales are found on the upper surface of the leaves, whereas most soft scales are on the underneath of the leaves.
Distribution S. and E. Africa, Madagascar, Australia, S. China and Japan; also the Seychelles and Hawaii.
Control Not often required. Natural levels of parasitism are generally high. Diazinon and malathion as aqueous sprays, repeated after 2–3 weeks, would probably be effective in controlling this insect, as also would be dimethoate.

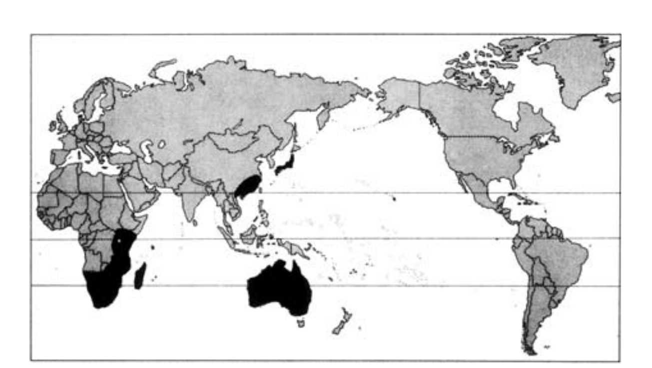
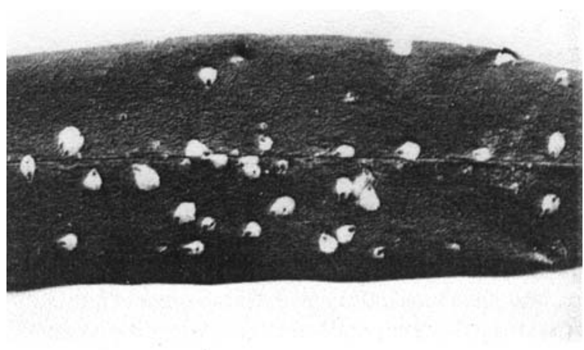
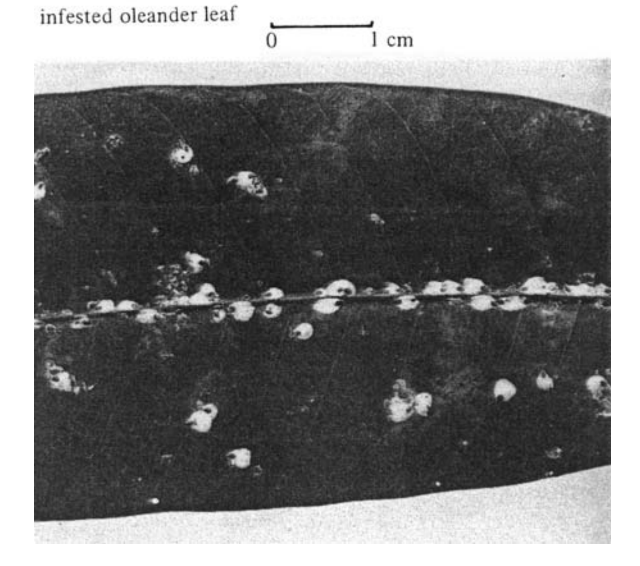


Fig. 9.116. Phenacaspis cockerelli (Mango Scale); S. China.





Quadraspidiotus perniciosus (Comstock)
(= *Aspidiotus perniciosus* Comst.)

Common name San José Scale
Family Diaspididae
Hosts (main). Apple, peach, pear, plum, currants.
(alternative). Most deciduous fruit trees and shrubs; wide range of other trees and shrubs; polyphagous on woody plants; more than 700 host plants recorded.
Damage Tiny circular scales can be seen on the bark of lightly infested trees, or on the fruits; in a heavy infestation the bark may be completely covered with overlapping scales; bark cracks, exudes sap, whole tree may die.
Pest status A very serious pest of deciduous fruit trees and bushes; infested trees may die, and fruit is unsalable. Entire orchards debilitated and even destroyed.
Life history One of the few viviparous hard scales, each female producing 100–400 nymphs. The crawlers are minute (0.2 mm), yellow and very active. Overwintering occurs in the nymphal stage.

The adult female is subcircular, flattened but with a raised central nipple, grey in colour, 1–2 mm in diameter, and completely covered by the circular yellow scale. Male scales are oval, about 1 × 0.5 mm.

Total life-cycle takes 18–20 weeks in California, and in the warmer parts of the world there may be 4–5 generations per year.
Distribution Essentially a subtropical species, but extending throughtout Japan and into Canada; probably summer temperatures are the key factor to its distribution. In Europe found in Switzerland and Germany, but not yet recorded in the UK (CIE map no. A.7).
Quadraspidiotus juglansregiae (Comstock) – (Walnut Scale) USA.
Quadraspidiotus ostraeformis (Curt.) – (Oyster Scale) on apple, peach, pear, apricot, plum, cherry, nectarine, currants, and birch; Europe, USA, Canada.
Quadraspidiotus pyri (Licht.)–(Pear Scale) on pear, apple, peach, poplar and ash; Europe.
Control As an extremely important fruit pest there is legislation in most countries against this species being accidentally introduced and established; there are also international phytosanitary regulations. For chemical control see page 224.

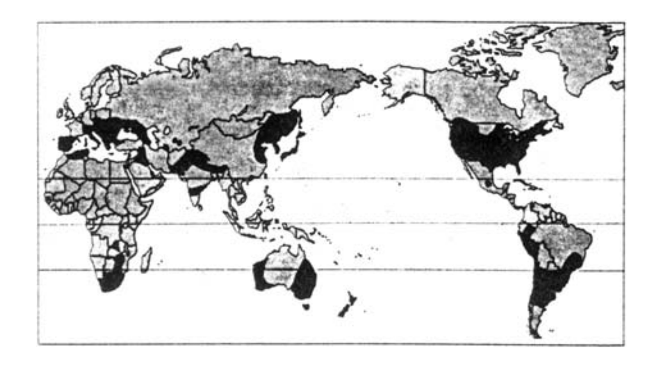
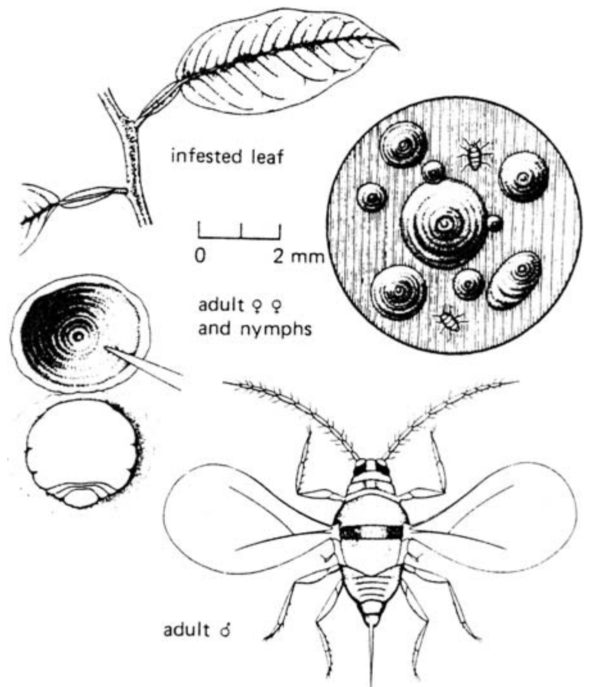


Fig. 9.117. Quadraspidiotus perniciosus (San José Scale).



Order **HETEROPTERA**

Some of these bugs are aquatic and predaceous, some are terrestrial and predators, and some are plant feeders which imbibe sap; all have piercing and sucking mouthparts. All species have toxic saliva which when injected into a plant produces necrosis and death of tissues, resulting sometimes in the death of shoots and branches. The forewings (hemelytra) have the basal two-thirds thickened and the end third is membraneous; the wings are held flat over the body.

Family **Miridae (= Capsidae)**

(Capsids or Mirids) Medium to small-sized bugs; usually pale in colour and delicate in structure; no ocelli. A very large family of about 6000 species. Most feed on plant sap but a few are predators. Many are important crop pests. Many species have a curious, knobbed, pin-like structure projecting from the thorax.

Family **Lygaeidae**

Small, dark or brightly coloured forms; somewhat like smaller, softer, brighter coreids. Most are plant feeders, but a few are predatory. A large family with about 2000 species.

Family **Pyrrhocoridae**

(Red Bugs) Moderately-sized, brightly coloured insects without ocelli; the coloration is usually brightly contrasting. A small family; the only genus of agricultural importance is *Dysdercus*, the Cotton Stainers.

Family **Coreidae**

Medium to large angular bugs, generally dull in colour; ocelli are present; they frequently have dilatations on the legs and antennae. The toxic saliva causes severe damage to attacked plants. More than 2000 species have been described. Many species have stink glands.

Family **Tingidae**

(Lace Bugs) The body and hemelytra are densely reticulate, hence the name 'Lace Bugs'. They are very characteristic and easily recognized. Ocelli are absent and the scutellum is concealed by the pronotum. About 700 species are known; they exhibit great diversity of form.

Family **Pentatomidae**

(Stink Bugs) Moderate to large insects; the head has the lateral margins concealing the bases of the antennae; ocelli are almost always present; the scutellum is always large. A large family with over 3000 species listed; most are plant feeders but some are predaceous. Most species have stink glands which emit a characteristic unpleasant odorous liquid.

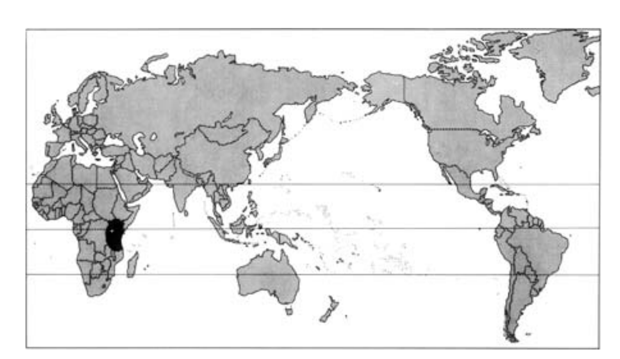
Family **Scutelleridae**

(Shield Bugs) Very similar to Pentatomidae but with the scutellum enormous and extending over the tip of the abdomen.

Helopeltis anacardii Miller

Common name Cashew Helopeltis
Family Miridae (= Capsidae)
Hosts (main). Cashew
(alternative). Only sweet potato is recorded.
Damage Distortion of young leaves with angular lesions along the main veins. Elongate dark lesions on green shoots, sometimes accompanied by the exudation of gum; brown sunken spots on developing apples and nuts. Bunched terminal growth follows a severe attack.
Pest status A sporadically serious pest of cashew in Coast Province, Kenya.
Life history Eggs are laid embedded in the soft tissues near the tips of flowering or vegetative shoots. The egg-cap bears two fine, white, thread-like processes which are visible externally.

There are five nymphal stages, the last one being yellowish in colour and about 4 mm long. Both nymphs and adults have a knobbed, hair-like projection sticking upwards from the thorax. Young nymphs feed on the undersides of young leaves. Older nymphs feed on the young shoots and developing fruits. The latter may be shed if attacked when very young. Severely damaged shoots die back and the subsequent development of numerous auxillary buds causes a 'witches broom' type of growth to appear.



The adults generally resemble the mature nymph but are more orange-brown, and are larger (males 4.5 mm; females 6.0 mm) and have transparent wings extending beyond the tip of the abdomen. Adults may live for 2–3 weeks.

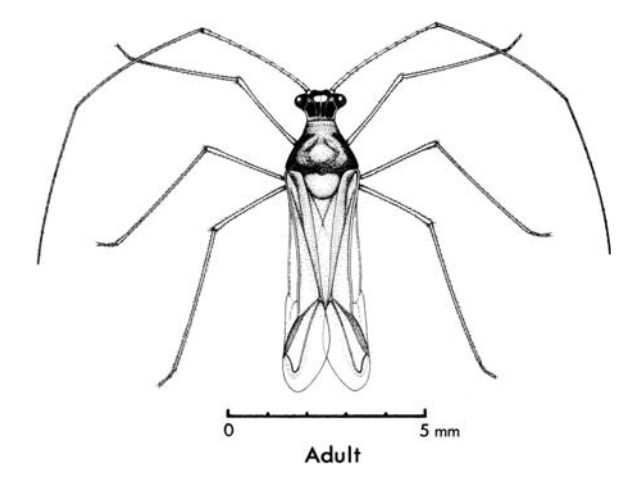
After a pre-oviposition period of some 12 days the females may lay 3–4 eggs per day until they die.

The total life history, including the 12-day pre-oviposition period, takes about 48 days.
Distribution E. Africa. Other species of *Helopeltis* are important pests of cashew in Africa and S.E. Asia.
Control Chemical control measures must be very promptly applied to be effective. Great vigilance is needed in the July-December period or an infestation will easily be overlooked until it is too late to take effective action.

Seedling trees up to 1½ years old: dusting with BHC or carbaryl was recommended, repeated if necessary at weekly intervals.

Trees 1½–5 years old should be sprayed with a higher strength BHC solution, preferably applied with a mist blower; repeated if necessary after three weeks.

Fig. 9.118. Helopeltis anacardii (Cashew Helopeltis); Kenya.



Helopeltis schoutedeni Reuter

Common name Cotton Helopeltis
Family Miridae (= Capsidae)
Hosts (main). Cotton (polyphagous)

(alternative). A wide range of wild and cultivated plants including tea, cocoa, castor, cashew, mango, avocado, peppers, guava, and sweet potato.

Damage Plants are stunted and with numerous secondary branches, and black lesions on the stems. The leaves are rolled downwards at the edge and with many brown-centred black lesions especially near the main veins. Similar crater-like lesions on large green bolls are found. If the cotton is severely attacked when young it appears as if it has been scorched by fire.

Pest status A sporadic pest of cotton in various parts of Africa. Affected fields may be very severely damaged with adjacent fields almost untouched.

Life history The eggs are test-tube-shaped with a rounded cap and two unequal, hair-like filaments at one end. Eggs are white and about 1.7 mm long. They are completely inserted into soft plant tissues, only the cap and filaments being visible externally. Most eggs are laid in the leaf stalk or main veins, and hatching takes place after about two weeks.

The nymphs are slender delicate insects, yellow with pale red markings. The full-grown nymph has a body length of about 7 mm, the antennae being much longer. There are five nymphal instars all except the first having a pin-like projection sticking up from the thorax. The total nymphal period is about three weeks.

The adult bug is 7–10 mm long with antennae nearly twice as long as the body. The antennae, head and wings are blackish. Most females have a blood-red body, and like the nymphs the adults have a pin-like projection on the thorax. After a pre-oviposition period of several days the adult female bug may live 6–10 weeks and lay 30–60 eggs.

Distribution Africa; from W. through to E., and S. to Zimbabwe (CIE map no. A297). Several other species of *Helopeltis* are pests in Africa and S.E. Asia.

Control *Helopeltis* attacks occur very suddenly and great vigilance is necessary if they are to be effectively controlled. The pesticiders usually recommended as sprays were DDT, HCH, carbaryl or phenthoate.

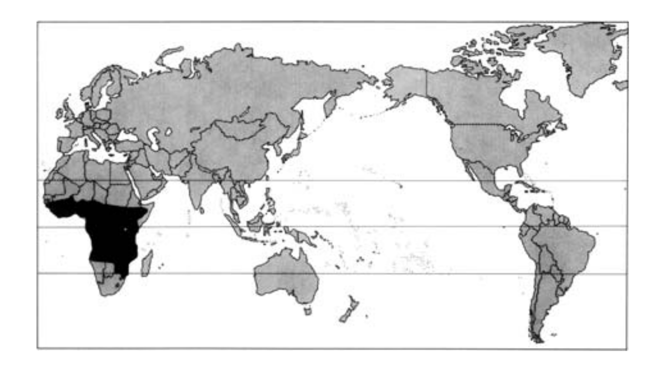
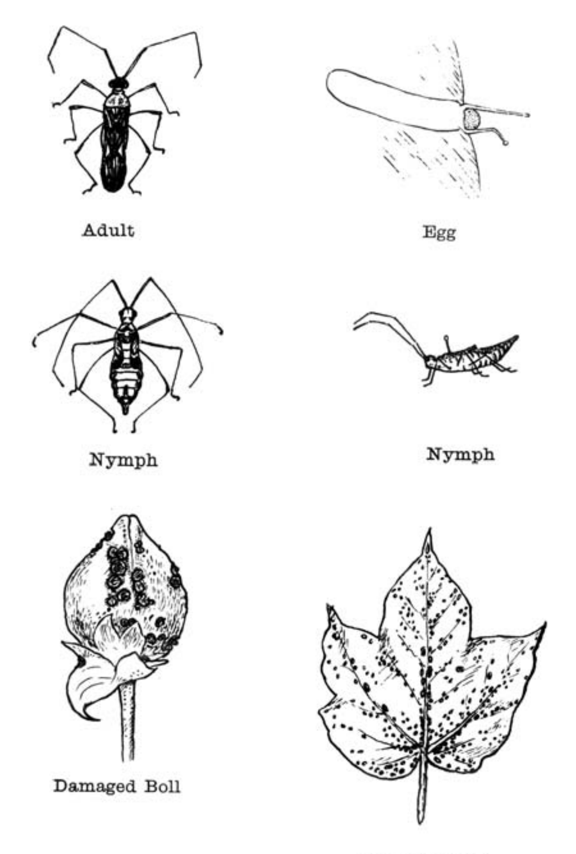


Fig. 9.119. Helopeltis schoutedeni (Cotton Helopeltis); Kenya.



Lamprocapsidea coffeae (China)

Common name Coffee Capsid
Family Miridae (= Capsidae)
Hosts (main). Coffee: *arabica* and *robusta*.

(alternative). The Coffee Capsid has been recorded on a *Tricalysia* sp. but it appears to prefer coffee.

Damage Flower buds blacken due to the death of the stamens and, later, the petals. The style, however, remains healthy and usually elongates. The resulting appearance is club-like, the club having a pale green shaft and a black head. The damage is due to the injection of toxic saliva by both adults and nymphs. No fruit is set by affected flowers.

Pest status A sporadically serious pest of both *arabica* and *robusta* coffee in various areas. It is frequently beneficial on unshaded coffee at lower altitudes, since the pruning effect of capsid damage reduces the tendency to overbear.

Life history The eggs are completely inserted into a flower bud; they cannot be detected in the field.

The nymphs are pale green and pear-shaped. There are five instars, wing buds being visible on the fourth and fifth stages. The fifth stage is nearly 6 mm long. The nymphal period is variable depending upon the food available, but can be as little as two weeks.

The adult bug is green and about 6 mm long. About half-way along the wings is a sharp downward bend so that both the top and posterior part of the abdomen is covered by them. The adult bug can live for at least three weeks. Both adult and nymphs feed on flower buds if they are present, but in their absence on any soft green part of the bush.

Distribution Africa; Zaïre, Madagascar, and E. Africa.

Control Control measures should only be applied when: developing flower buds are present; the farmer requires most of these buds to set fruit; the population of Coffee Capsid Bugs is more than an average of four to a tree.

The following insecticides can be used: fenitrothion, fenthion, or pyrethrum as sprays in water, applying 0.5–0.9 litres per tree according to the amount of leaf present.

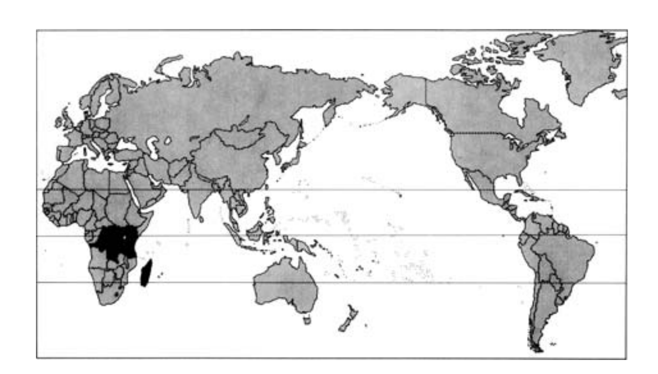
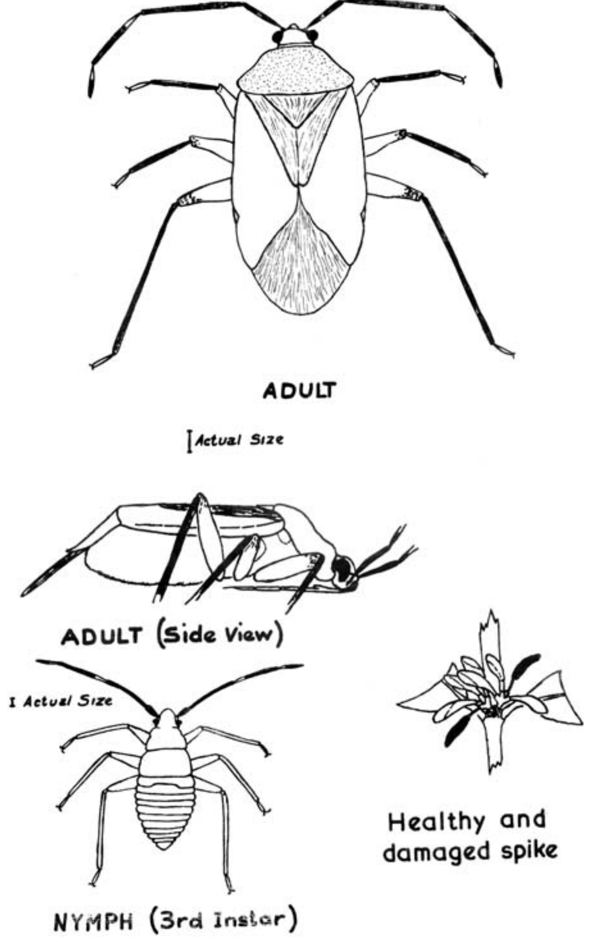


Fig. 9.120. Lamprocapsidea coffeae (Coffee Capsid); Kenya.



Sahlbergella singularis Hagland

Common name Cocoa Capsid
Family Miridae (= Capsidae)
Hosts (main). Cocoa
(alternative). *Cola* spp., *Ceiba pentandra*, and *Berria* spp.
Damage Both nymphs and adults feed on the pods and young shoots, and this species of mirid usually prefers mature trees. The toxic saliva injected through the feeding puncture causes a dark spot, frequently becoming infected with fungus. Each bug may make 24–36 punctures a day. After pod harvesting many bugs move to the tree canopy and feed on the young shoots; extensive damage is referred to as 'capsid blast', and severely attacked trees may die.
Pest status This insect can be a serious pest in cocoa plantations, but is usually more serious to crops grown by peasant farmers. It is not a very serious pest in E. Africa, but has been so in Ghana, Nigeria, and the Ivory Coast.
Life history Eggs are laid on twigs, pods or pod stalks, by being inserted into the plant tissues.

After 12–18 days the nymphs emerge, and the nymphal stage lasts some 25 days.

The adult is about 15 mm long, and speckled brown. After a week the female will start egg-laying, which persists until the end of her life some five weeks later.
Distribution W. Africa (Ghana, Nigeria, Sierra Leone, Ivory Coast and Togo) through to Zaïre and Uganda (CIE map no. A22).
Control A spray of lindane in water used to be effective, followed by a second spray of half strength after four weeks. In some areas resistance is now established, and alternative insecticides are propoxur, or monocrotophos painted on to young trees.

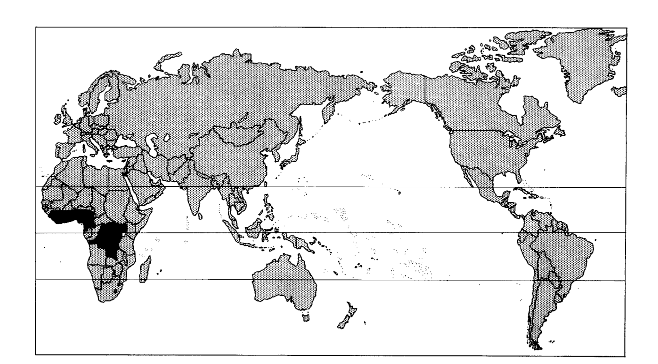
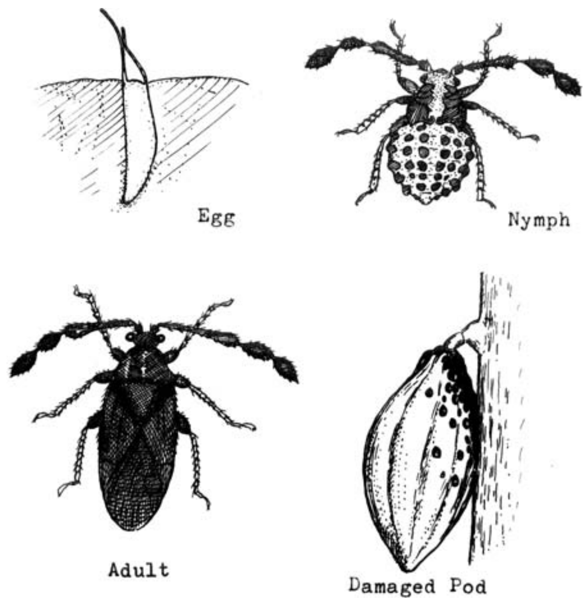


Fig. 9.121. Sahlbergella singularis (Cocoa Capsid); Uganda.



Taylorilygus vosseleri (Popp.)

(= *Lygus vosseleri* Popp.)

Common name Cotton Lygus
Family Miridae (= Capsidae)
Hosts (main). Cotton

(alternative). Sorghum, sesame, and various wild and cultivated legumes; recorded from plants in 14 different families.

Damage Damaged plants are tall and straggly with very short side-branches; the leaves are holed, ragged, and tattered. Small flower buds turn brown and are shed. Very young bolls are shed and have black spots on the boll wall where they were punctured.

Pest status A major pest of cotton in parts of E. Africa but in other areas damage may be rare and sporadic, and this pest is now not considered to be so important as was once thought. Sorghum is a most important alternative host, for large populations build up when the grain is in the milky stage, and as the grain ripens the bugs make mass migrations on to nearby cotton.

Life history The egg is small, test-tube-shaped and about 0.75 mm long. It is inserted completely into the soft tissues of the plant, the flat end being level with the plant surface. Hatching after eight days.

The full-grown nymph is about 4 mm long; the body is egg-shaped and pale green. The legs are fairly long and slender; there are five nymphal instars and the total nymphal period lasts about 17 days.

The adult bug is 4 mm long, brown with a greenish tinge and with the hind part of the wings bent sharply down over the end of the abdomen. Adult females may live for 40 days and lay 60 eggs.

Distribution Tropical Africa from W. through to E., and Madagascar.

Other species of *Lygus* attack cotton in the USA, and also other crops in Europe and Asia.

Control Recommended insecticides include DDT, trichlorphon and carbaryl.

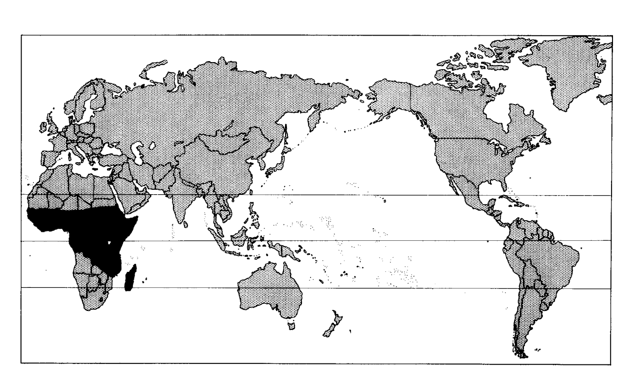
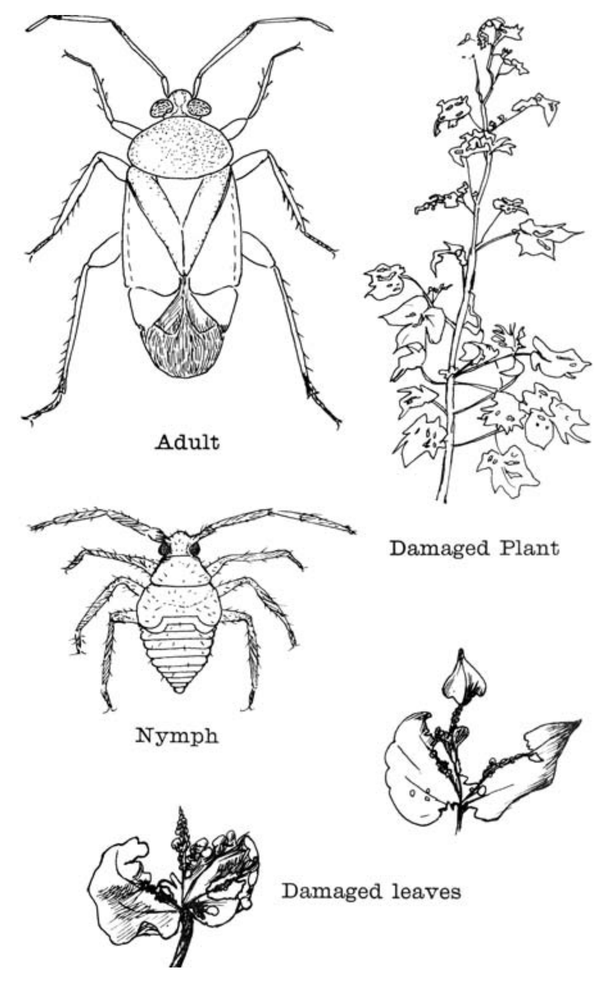


Fig. 9.122. Taylorilygus vosseleri (Cotton Lygus); Kenya.



Oxycarenus hyalinipennis (Costa)

Common name Cotton Seed Bug
Family Lygaeidae
Hosts (main). Cotton
(alternative). Okra, and other Malvaceae; *Sterculia* spp. and *Ceiba* sp., Persimmon (Israel).
Damage The lint of the opened boll is stained, and deteriorated in quality. The seeds show brown discoloration and severe shrinking, and seed germination is severely reduced.
Pest status An important pest of cotton affecting lint quality and seeds.
Life history The egg is creamy, oval, about 1 by 1.2 mm, longitudinally striated and with six projections at the anterior end. Eggs are laid singly or in small groups loose amongst the seeds in the open boll. Each female lays 25–40 eggs, and incubation takes 4–10 days.

The five nymphal instars take about 2–3 weeks. All stages emit a characteristic unpleasant smell if crushed.

The adults are small, elongate bugs with pointed heads, about 4 mm long and 1.5 mm broad, dark brown or black with a red abdomen, and translucent hemelytra.

Breeding can only take place when ripe or nearly ripe seeds are available. The whole life-cycle can be completed in as little as three weeks; 3–4 generations usually take place in each crop ripening.
Distribution Recorded from cotton throughout continental Africa, Egypt, Middle East, to India, Indo-China, and the Philippines; introduced accidentally into Brazil. (CIE map no. A. 433).

Seven other species of *Oxycarenus* are also recorded from cotton in Africa.
Control Control can be effected by sprays of carbaryl or dusts, applied when the bugs are seen on the half-opened bolls.

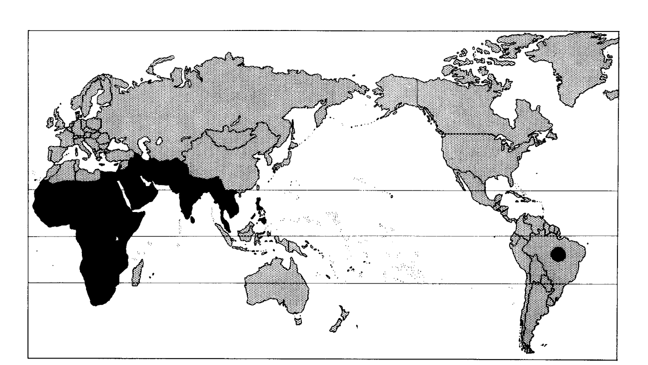
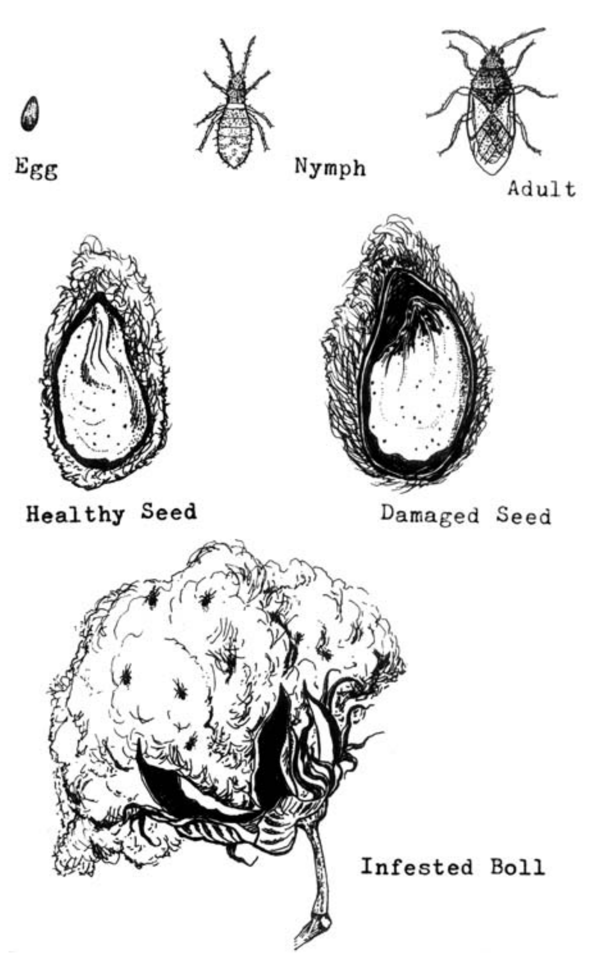


Fig. 9.123. Oxycarenus hyalinipennis (Cotton Seed Bug); Kenya.



Dysdercus spp.
cingulatus (F.) (= *D. ornatus* Bredd.)
fasciatus Sign.
nigrofasciatus Stål
superstitiosus (F.)
spp. (10 +) in New World

Common name Cotton Stainers (Red Cotton Bugs)
Family Pyrrhocoridae
Hosts (main). Cotton (Malvaceae)
(alternative). Many plants and trees including sorghum, *Hibiscus* spp. (okra, etc.), *Abutilon*, Hollyhock, *Aznaza*, *Sterculia*, baobab and kapok trees.
Damage There are conspicuous red bugs on the cotton bush, which fall to the ground if the bush is shaken. Small green bolls may abort and go brown, due to death of the seeds, but they are not shed. No damage is visible externally on large green bolls but, if the inner boll wall is examined, warty growths or water-soaked spots can be seen corresponding to patches of yellow staining on the developing lint. In very severe attacks the whole lock may be brown and shrunken.
Pest status A major pest of cotton in most parts of Africa, and Asia; not important in the USA.
Life history The eggs are ovoid, 1.5 × 0.9 mm, yellow when first laid but turning orange. Hatching takes about 5–8 days. They are laid in batches of about 100 in moist soil or plant debris; moisture is essential for development and the eggs die if the soil dries out.

There are five nymphal instars. The first instar nymphs do not feed but require moisture and usually congregate near the empty egg shells. The second and third instars feed gregariously on seeds on or near the ground. Later instars wander freely over the plant seeking suitable fruits and seeds. Nymphs are often found in large numbers on posts, tree trunks, etc. where they prefer to moult. The full-grown nymph is a bright red bug with black wing pads and is about 10–13 mm long, according to species. The total nymphal period lasts about 21–35 days.

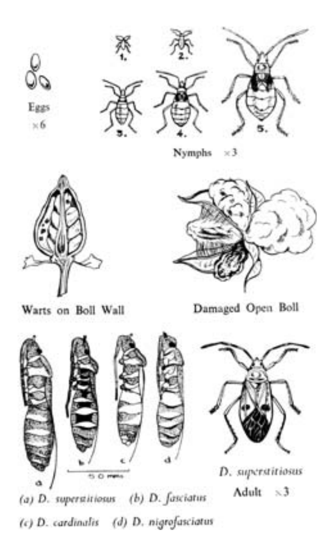
The adult male Stainer is 12–15 mm long, according to species; the female is slightly larger. The wings are reddish and each has a black spot or bar near the middle. Stainers are able to fly strongly but usually drop to the ground and crawl if disturbed on the bush. Dispersal flights of up to 15 km have been recorded. The bugs feed by sucking sap from the seeds; the piercing and sucking proboscis is pushed through the boll wall and into the seeds. More eggs are laid by the female if she feeds on mature exposed seeds. After a pre-oviposition period of 5–14 days adult females may live a further 60 days and lay a total of 800–900 eggs.

The most serious damage done by Stainers is the injection of fungal spores of the genus *Nematospora* into the boll; the fungus grows on the lint and causes the staining.
Distribution Found in the cotton-growing areas of tropical Africa, tropical Asia, Australasia, USA, C. and S. America.
D. cingulatus – CIE map no. A265.
D. fasciatus – CIE map no. A266.
D. sidae Montr. – CIE map no. A267, also in Australasia.
At least 10 species of *Dysdercus* on cotton in Africa, and a larger number in the New World.
Control Cotton Stainers may be controlled by caging chickens in cotton plots using chicken wire; about 15 birds will keep about 0.1 ha free of Stainers. This method should *not* be combined with a chemical treatment, and is most appropriate to a small plot grown next to the homestead.

In parts of Kenya where the Mutoo tree is an important Stainer host it should be cut back each year in December or January to prevent fruiting during the cotton season.

The usual insecticides used were either carbaryl, HCH, or phenthoate as a spray or a dust mixture of BHC and DDT.

Fig. 9.124. Dysdercus spp. (Cotton Stainers)



Clavigralla spp.
(= **Acanthomia** spp.)
horrida (Germ.)
tomentosicollis (Stål)

Common name Spiny Brown Bugs
Family Coreidae
Hosts (main). Beans (*Phaseolus* spp.), pigeon pea, and *Dolichos labab*.

(alternative). Other pulse crops, Leguminosae, and *Solanum incanum*, Passion Fruit.

Damage The external symptoms of *Acanthomia* damage on beans are dimpling of the seed coat, browning and shrivelling of the seed, and wrinkling of the seed coat. Germination ability of the seed is also impaired. These symptoms are thought to be caused by the fungus *Nematospora coryli*, rather than by the feeding bug itself.

Pest status In parts of Africa these are serious pests of beans; experimental work has shown that with an infestation of only two bugs per plant the expected weight of seeds was lowered by 40–60%, the number of seeds by 25–36%, and the seed quality by 94–98%, according to the species of bug concerned. There appears to be no correlation between local infestations one year and the succeeding year.

Life history Eggs are laid on the foliage of the plants and take 6–8 days to hatch under field conditions.

The different nymphal instars (five) take the following times for their development: first instar, 2–4 days; second, 3–5 days; third, 4–6 days; fourth, 4–6 days; fifth and last instar, 6–8 days. The total time for nymphal development in the field is about 28–35 days; in the laboratory this time was from 16–61 days, according to temperature (30–18°C).

The adults are small brown bugs, 7–10 mm in length, according to species.

A fungus (*Nematospora coryli*) is often associated with *Acanthomia* damage, but it is not yet certain whether the fungus is introduced by the bug itself, or whether it enters the seed after feeding via the feeding punctures.

Distribution *A horrida* is found in E. Africa, Nigeria and Somalia. *A. tomentosicollis* is recorded from (CIE map no.A.445) E. Africa, Nigeria, Guinea-Bissau and S. Africa.

Control When insecticidal treatment is required a spray of DDT or endosulfan was recommended. Endosulfan is often used in *Heliothis* control.

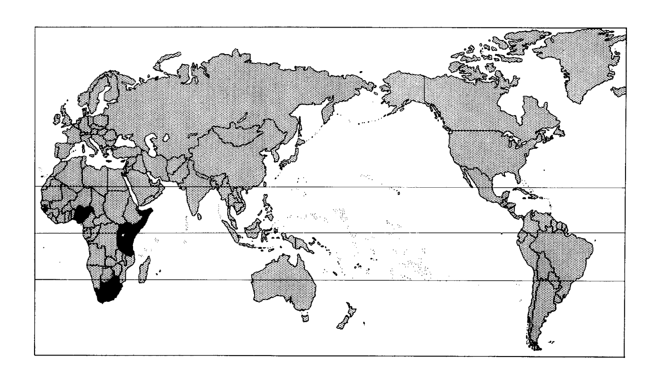
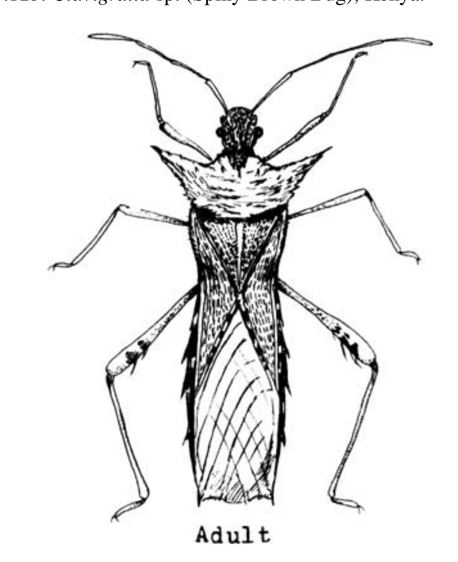


Fig. 9.125. Clavigralla sp. (Spiny Brown Bug); Kenya.



Leptoglossus australis (F.)) and spp.
(= *L. membranaceus* (F.))

Common name Leaf-footed Plant Bug (Squash Bug)
Family Coreidae
Hosts (main). Cucurbits

(alternative). *Citrus* spp., groundnut, and many legumes; sometimes found on oil palm in Malaysia, passion fruit in Kenya; and coffee, yam, sweet potato, cacao, and rice.

Damage The young fruits show dark spots where feeding punctures have been made. Many immature fruits fall prematurely. The terminal shoots are fed upon and they may wither and die off beyond the point of attack. Similar damage is seen on *Citrus*. Most feeding sites become infected by fungi.

Pest status Not a very serious pest, but quite common and widely occurring, and fairly polyphagous in habits.

Life history The adult is a large, brown bug about 20–25 mm long, with characteristic tibial expansions on the hindlegs, and a pale orange stripe across the anterior edge of the mesonotum. The antennae have alternating black and pale orange zones. In Java development takes about 40 days.

Distribution Canary Isles, W., C. and E. Africa down to the Transvaal, Madagascar, India, Sri Lanka, Burma, S.E. Asia, S. China, Philippines, Indonesia, Papua New Guinea, West Irian, the Pacific Islands and N. Australia (CIE map no. A243).

A closely related species *L. zonatus* occurs on *Citrus* in C. and S. America.

Control Despite the abundance of this insect control measures are seldom required, but both BHC and parathion are effective against these bugs.

L. coreulus (say) (Southern Pine Seed Bug) – on seeds of *Pinus.*
L. occidentalis Heid. (Western Conifer Seed Bug) – a seed pest of several conifers, in the USA.

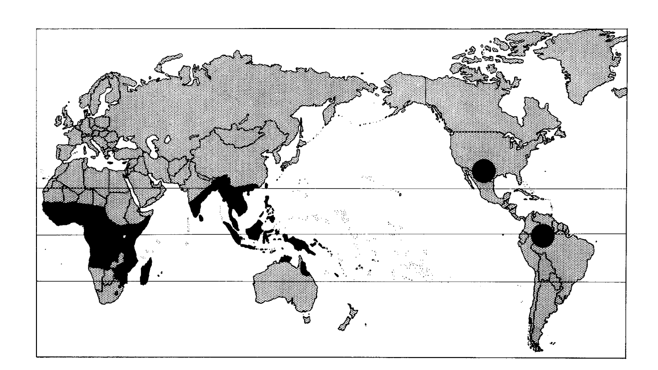


Fig. 9.126. Leptoglossus australis (Leaf-footed Plant Bug); S. China.



Notobitus meleagris (F.)

Common name Bamboo Bug
Family Coreidae
Hosts (main). One or two large species of bamboo.
(alternative). Not known.
Damage The toxic saliva injected into the plant stem at the time of feeding causes death of plant cells and necrosis; as the plant grows so the necrotic area increases in size, usually as a longitudinal split, severely weakening the bamboo stem for any constructional purposes.
Pest status Possibly a serious pest in some areas where large bamboos are grown for constructional purposes, but at present only recorded from S. China More of academic interest than directly agricultural.
Life history Breeding takes place under the large leaf sheath surrounding the base of each stem internode. Under any one sheath there may be 3–15 nymphs of different ages as well as several adults. On some branching stems the developing lateral shoots may carry several bugs and sometimes the feeding of the bugs kills the young lateral shoot completely.

The adult bug is a large brown coreid, of regular body shape, and with normal legs; it is some 20–24 mm in body length.

This is a very typical coreid bug, both in appearance and habits, and resembles many other species. The saliva is apparently very toxic and feeding results in typical necrotic lesions on the stem and death of young sideshoots.
Distribution To date only recorded from S. China.
Control In the infestations under observation control was not regarded worthwhile as the plants were grown for ornamental purposes.

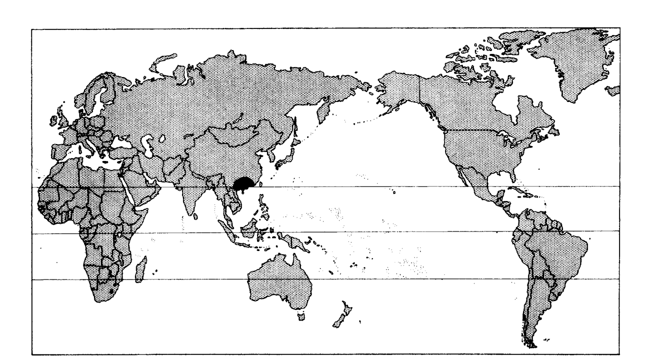
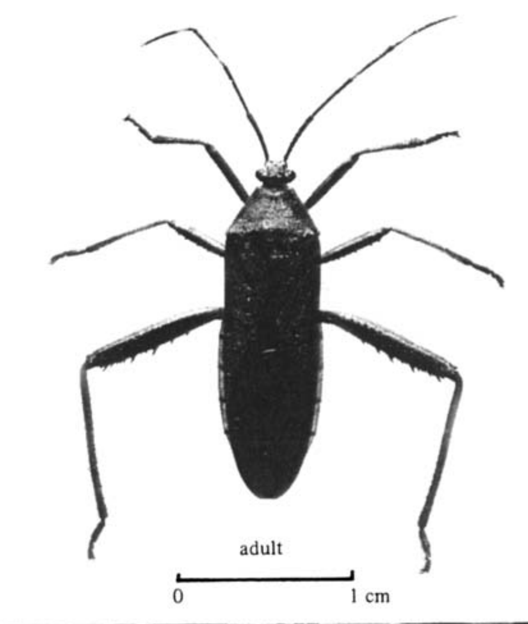
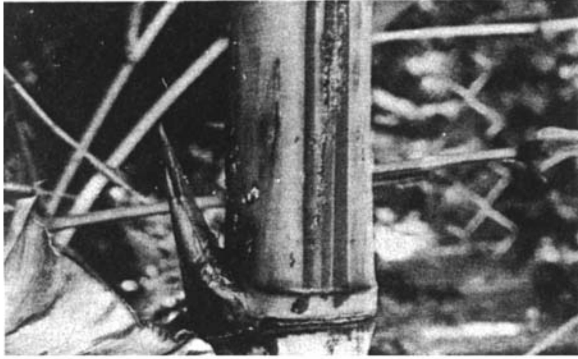


Fig. 9.127. Notobitus meleagris (Bamboo Bug); S.China.





necrosis of bamboo stem caused by toxic saliva of feeding bugs

Pseudotheraptus spp.

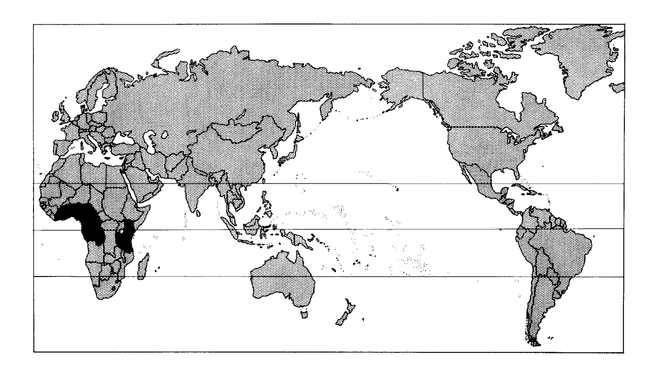
P. wayi Brown
P. devastans (Dist.)

Common name Coconut Bugs
Family Coreidae
Hosts (main). Coconut

(alternative). Cashew, *Cinnamomum*, cassava, mango, rubber, guava, cocoa, and various wild legumes.

Damage This bug is responsible for 'early nutfall' or 'gummosis' of coconuts in E. Africa. Young nymphs feed in the developing spadix at the base of the male flowers, or in the main stem and young branches which are still succulent. Older nymphs and adults tend to feed more on the developing nuts and female flowers. The toxic saliva of the bugs causes necrotic spots to appear. The young nuts are frequently killed (and dehisce) by the toxic saliva.

Pest status A serious pest in parts of E. Africa on coconut, but actual crop loss is difficult to assess, partly because of the natural nut-fall. Over 70% of young nuts will fall 'naturally' and so many of the bug-damaged nuts would fall anyway. Two bugs per palm can cause appreciable damage. Very closely related species are found in Zaïre, Uganda and W. Africa.



Life history Eggs are laid singly in the flowers or on young nuts. Each female can lay on average at least 70 eggs (probably about 100). The development time required for hatching is 8–9 days.

There are five nymphal instars taking a total of 33 days (at 24.6°C).

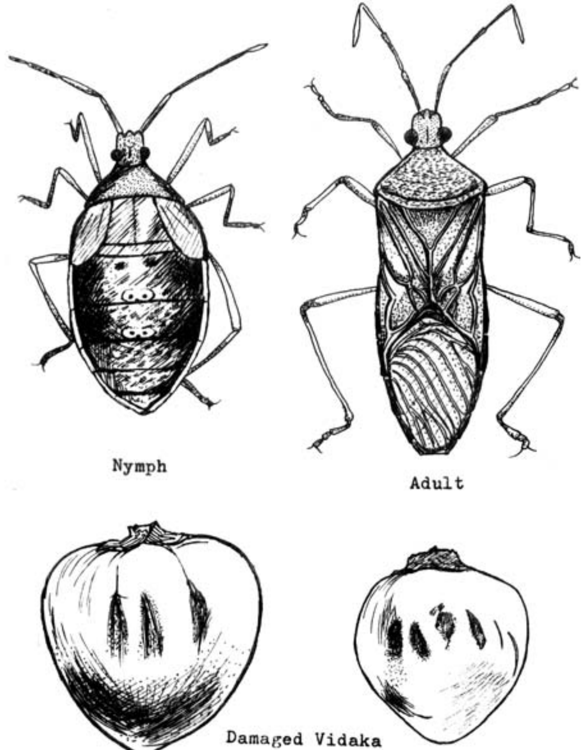
The adult is a medium-sized coreid bug, fawn or brown, with the membrane blackish. The pre-oviposition period in the female is nine days.

This species breeds continuously on the coconut palm and probably has nine generations per year.

Distribution Found only in Africa; East, West, and Central (CIE map No. A. 472).

Control The ant *Oecophylla longinoda* nests in palms and other trees and if present those palms are seldom inhabited by Coconut Bugs. Other predatory ants (*Anoplolepis custodiens, A. longipes*, and *Pheidole punctulata*) will remove *O. longinoda* colonies, but without preying on Coconut Bugs, and will allow the pest to severely damage palms occupied by them. The *Anoplolepis* species are largely confined to sandy soils for nesting purposes and palm trunks can be sprayed with dieldrin to stop them ascending to destroy the beneficial arboreal ant species. Dieldrin is also effective against *P. punctulata* in coffee plantations.

Fig. 9.128. Pseudotheraptus wayi (Coconut Bug); Kenya.



Leptocorisa acuta (Thunb.)

Common name Rice Seed Bug (Asian Rice Bug)
Family Alydidaè
Hosts (main). Rice
(alternative). Various species of wild grasses.
Damage The bugs usually appear in the young crop with the early rains, and both nymphs and adults suck sap from the developing grains at the 'milky' stage. All soft milky grain is susceptible to attack – the bugs suck the sap until the grain is emptied. Before the grain is formed the bugs will feed on succulent young shoots and leaves.
Pest status Rice Bugs are very destructive in areas where rainfall is evenly distributed throughout the year, and also in irrigated crops. Yield losses of 10–50% are common, and in severe infestations the entire crop may be destroyed.

Six other species of *Leptocorisa* are also pests of rice in different parts of the tropics.

Life history Eggs are laid in rows along the rice leaves; they are red to black in colour, and flat in shape. The incubation period is 5–8 days. Newly hatched nymphs are green, but they become browner as they grow. There are five nymphal instars, distinct colour changes occurring after each moult. The nymphal period lasts 17–27 days.

The adult bugs are slender and some 15 mm in length, greenish-brown in colour, and have been recorded to survive up to 115 days in favourable conditions. In the absence of rice plants the bugs live on wild grasses.

The complete life-cycle takes some 23–34 days, and there are several generations per year.
Distribution Found in Pakistan, India, Sri Lanka, through S.E. Asia to S. China, Philippines, Indonesia, Papua New Guinea, West Irian and N. Australia (CIE map no. A225).
Control The same control measures that are used for the various leafhoppers and planthoppers on rice are generally effective against this pest.

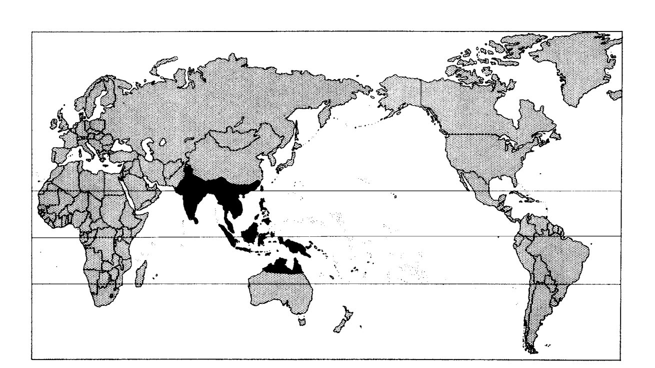
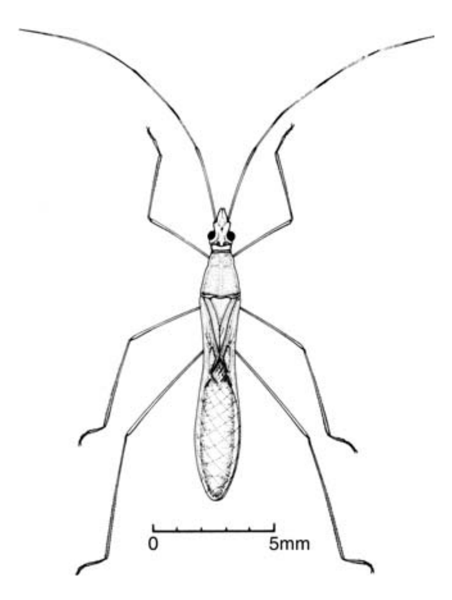


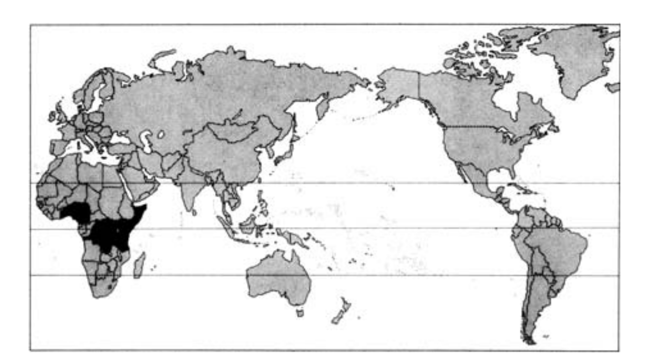
Fig. 9.129. Leptocorisa acuta (Asian Rice Seed Bug); S. China.



Stenocoris southwoodi Ahmad

(= *Stenocoris apicalis* (Westw.))
(= *Leptocorisa apicalis* (Stål))

Common name Rice Seed Bug (African Rice Bug)
Family Coreidae (Alydidae)
Hosts (main). Rice
(alternative). Various species of wild grasses.
Damage The bugs appear in the crop usually with the early rains, and both adults and nymphs suck the sap from developing grains at the 'milky' stage; they suck the sap until the grain is emptied. Before the grain formation stage the bugs feed on the young leaves and shoots.
Pest status A very destructive pest on both rain-fed and irrigated rice throughout tropical Africa. Yield losses of 10–40% are common, and in severe infestations the entire crop may be destroyed.

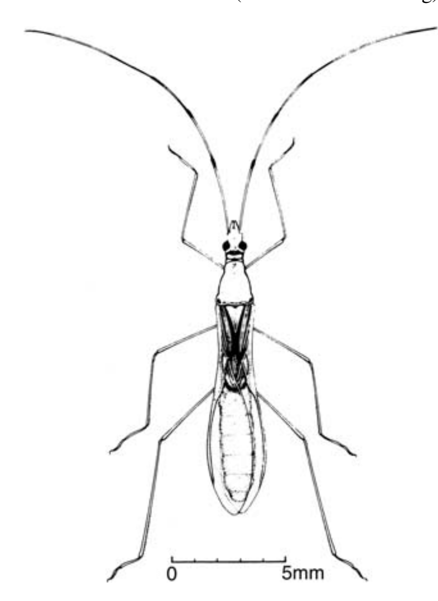


Life history Eggs are laid in rows along the rice leaves; usually dark red to black in colour, and flat in shape; they hatch after 5–8 days. Newly hatched nymphs are green, but they become more brown with each of the five moults; total nymphal period is 17–27 days.

The adult bugs are slender and some 15 mm in body length, greenish-brown in colour, and usually live for several months under favourable conditions. Dispersal flights are made at night occasionally during the season, and the bugs will then fly to lights.

The complete life-cycle takes some 23–34 days, and there are several generations per year.
Distribution This species is apparently confined to tropical Africa.
Control The same control measures recommended for the various planthoppers and leafhoppers on rice are generally effective against this pest.

Fig. 9.130. Stenocoris southwoodi (African Rice Seed Bug); Kenya.



Habrochila spp.
placida Horv.
ghesquierei Schout.

Common name Coffee Lace Bugs
Family Tingidae
Hosts (main). Coffee, especially *arabica*.
(alternative). None recorded.
Damage Yellow patches on the undersides of leaves covered with spots of shiny black liquid excreta. Severely attacked leaves turn completely yellow and then die from the edges inwards. The attack is often very localized at first, being confined to the lower leaves of a small group of coffee trees.
Pest status A sporadically severe pest of *arabica* coffee over most of Kenya. Since 1956 it has extended its range into different parts of Kenya – the recent outbreaks have followed the indiscriminate use of DDT. *H. placida* apparently prefers *robusta* coffee, and *H. ghesquierei, arabica*.
Life history Eggs are embedded in the undersides of leaves or in the soft tissues near the tips of green branches. Large numbers of eggs embedded near a growing point can cause checking or distortion of the terminal growth. The egg-caps, which are whitish, project slightly from the plant tissue and can just be seen with the unaided eye. Eggs hatch after 22–32 days.

There are five nymphal instars. The newly hatched nymph is about 0.75 mm long. The fully grown nymph is about 2 mm. The nymphs feed gregariously, exclusively on the lower leaf surface. Their development is complete in 16–36 days. They are ornamented with knob-like integumental processes on the head and body. The head is darkly pigmented in the later instars.

The adult Lace Bug is about 4 mm long. The wing carries a venation of lace-like pattern, giving the insect its common name. Dorsally, the thorax and wings carry domed outgrowths. The adults also feed on the lower surfaces of leaves but are not gregarious. Female maturation period is eight days.
Distribution E. Africa, Zaïre, Burundi, and Rwanda.
Control A predator (the mirid bug *Stethoconus* sp.) often keeps this pest down to low populations; spraying should only be done when the predator population is too low to keep the bugs in check.

The recommended insecticide for Lacebug control is fenitrothion as a foliar spray; if a good cover has been achieved with the spray a high kill of Lace Bugs will result; if, however, only a poor cover was achieved a second spray will probably be required after about one month. Synthetrc pyrethroids are also effective but should only be spot sprayed.

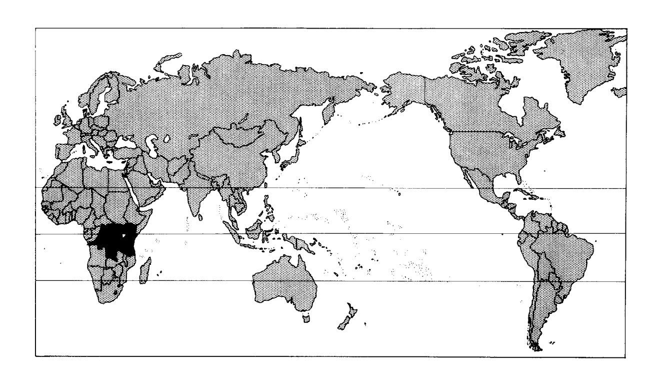
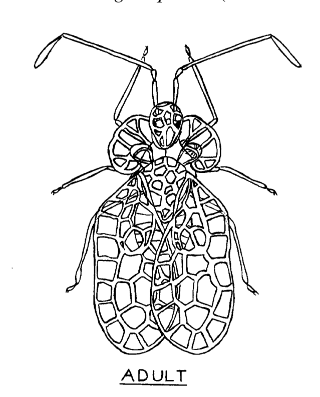
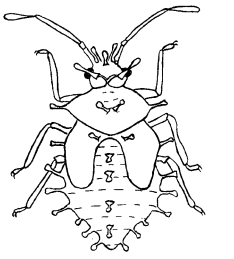
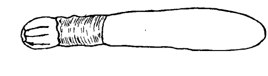


Fig. 9.131. Habrochila ghesquierei (Coffee Lace Bug); Kenya.







Stephanitis typica (Dist.)

Common name Banana Lace Bug
Family Tingidae
Hosts (main). Bananas
(alternative). Coconut, cardamom, manila hemp, *Alpinia* spp., and others.
Damage Leaves may be dwarfed or distorted, with yellow patches and necrotic spots; adults and nymphs may be seen congregated on the undersurface of the leaves.
Pest status In some situations this is quite a serious pest and control measures are required. Damage is sometimes accentuated as the adults are usually gregarious, and the combined effect of their feeding and the toxic saliva may be serious.
Life history Eggs are laid in the parenchymatous tissue of the leaves.

The adult is a small plant bug, some 5–6 mm in length (including the closed wings), and like most other Tingidae the wings are delicately but conspicuously veined. The thorax bears lateral expansions extending to the sides of the head.

One generation takes several weeks, so in hotter climates there may be many generations per year on perennial hosts.
Distribution From India and Sri Lanka through most of S.E. Asia, Indonesia, to Papua New Guinea, up through the Philippines to S. China, Taiwan, Korea and southern Japan (CIE map no. A308).
Control Chemicals that have given satisfactory control are carbaryl, fenitrothion, formothion, malathion and phosphamidon, as aqueous sprays, but care has to be taken to ensure the wetting of the undersides of the leaves.

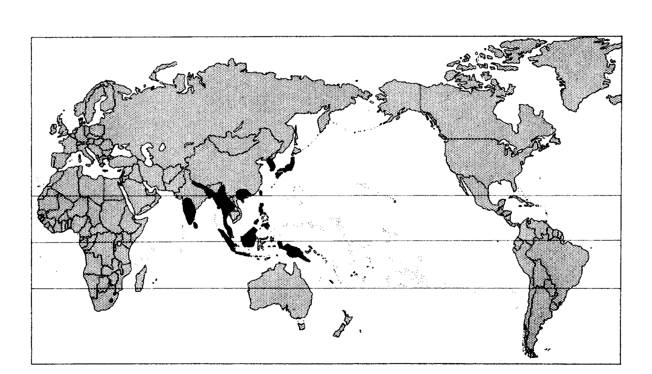
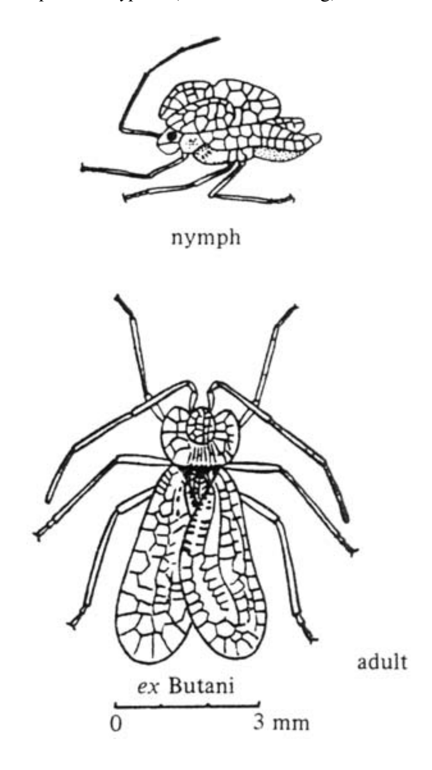


Fig. 9.132. Stephanitis typica (Banana Lace Bug); India.



Antestiopsis spp.
orbitalis (Westw.) group
intricata (Ghesq. & Carayon)

Common name Antestia Bugs
Family Pentatomidae
Hosts (main). Coffee (*arabica*).

(alternative). Antestia can live on various shrubs belonging to the same family as coffee, the Rubiaceae.

Damage Blackening of the flower buds; fall of immature berries; rotting of the beans within the berries or conversion of the substance of the bean to a soft white paste ('posho beans'); multiple branching and shortening of the internodes of terminal growth. The fungus *Nematospora* is associated with their feeding.

Pest status A major pest throughout Kenya and other parts of Africa, on *arabica* coffee; not a pest of *robusta* coffee.

Life history The eggs are whitish and are usually laid in groups of about 12 on the underside of leaves. They hatch after about ten days.

The newly hatched nymph is about 1 mm in length. There are five nymphal instars which resemble the adults in colour but have a more rounded shape and lack functional wings. The nymphal period lasts about 3–4 months.

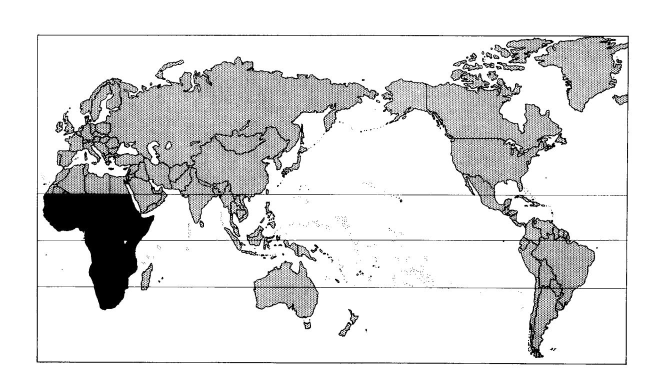
The body of the adult bug is shield-shaped, and generally dark brown, orange and white. Some races are much more brightly coloured than others. The body length is about 6 mm and the legs and antennae are easily visible. Adults can live for 3–4 months.

Distribution Confined mainly to the Ethiopian region, but is found throughout Africa.

Greathead (1966) describes three subspecies of *A. orbitalis* and four other species on coffee *arabica* in Africa, and four species of *Antestia*; CIE maps nos. A381 & A382.

Control Pruning to keep the bush open is of help in reducing bug population for Antestia Bugs prefer dense foliage.

Spraying should be done in Kenya when the average population (adults plus nymphs) is in excess of two per bush in the drier areas or one to a bush in the wetter areas. The recommended insecticides are fenitrothion, and fenthion, both as foliar sprays in water. If the infestation is heavy a second spray may be needed two weeks or more after the first. In Ethiopia fungus not present so economic threshold is 5 bugs/bush.



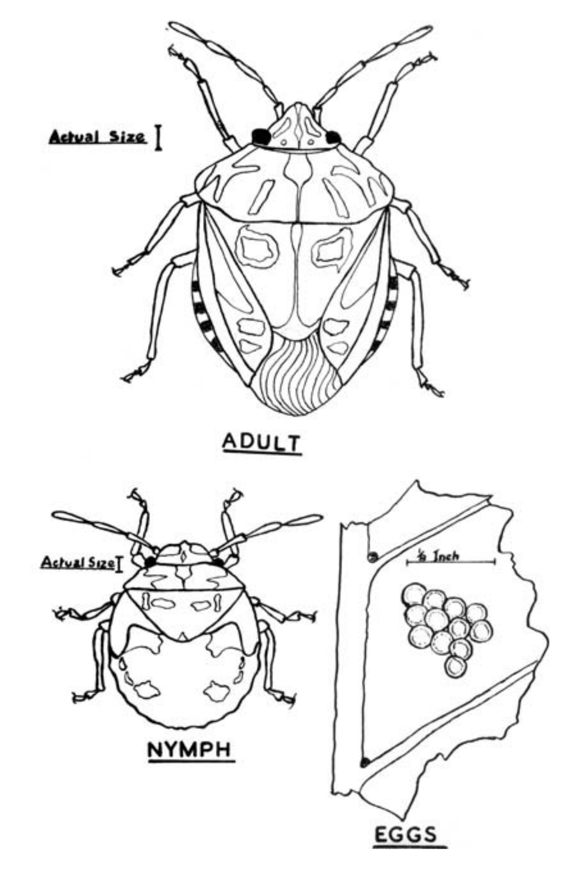
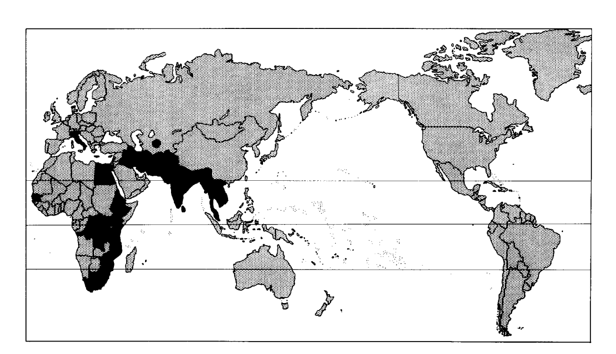


Fig. 9.133. Antestiopsis sp. (Antestia Bug); Kenya.

Antestiopsis spp.

hilaris (Burm.)
cruciferarum (L.)

Common name Harlequin Bugs
Family Pentatomidae
Hosts (main). *Brassica* spp.
(alternative). Other Cruciferae; also on beet, groundnut, potato, mallow. cotton, millet.
Damage Both adults and nymphs feed on the foliage of the crop, and the leaves wilt and dry. Young plants often die completely.
Pest status A major pest of cruciferous crops in many parts of the Old World.
Life history The eggs are white initially, but later turn orange; they are laid in small clusters either on the leaves or sometimes on the soil underneath. More than 100 eggs may be laid during a period of 2–3 weeks. The incubation period is 5–8 days.



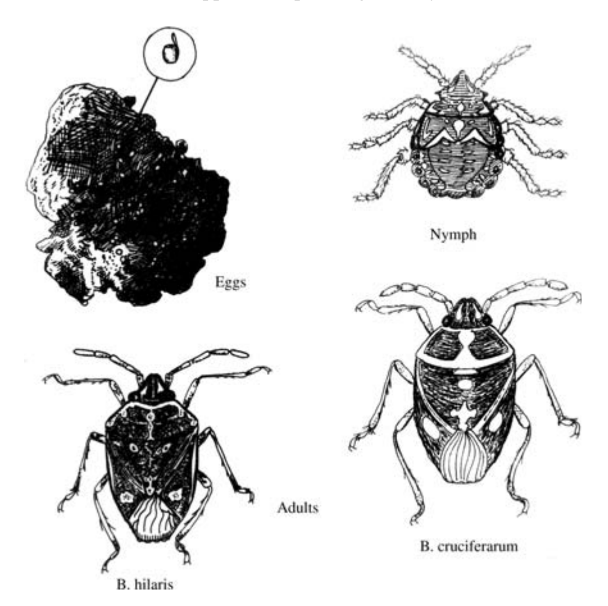
There are five nymphal instars, which take 2–3 weeks for development.

The adult bug is typically shield-shaped, 5–7 mm long and 3–4 mm broad. The upper surface has a mixture of black, white and orange markings (hence Harlequin Bugs).

The whole life-cycle takes only 3–4 weeks, and there are several generations per year.
Distribution *B. hilaris* is found in E. Africa, Egypt, Ethiopia, Malawi, Zimbabwe, Zaïre, Senegal, Mozambique, S. Africa, Italy, Iran, Iraq, Pakistan, India, Sri Lanka, Burma, and the USSR. (CIE map no. A417).
B. cruciferarum is recorded from E. Africa, India, Sri Lanka, Pakistan, S.E. Asia, and Afghanistan.
Control Destruction of all cruciferous weeds will help to prevent a population build-up.

Some of the effective pesticides used to control this pest are DDT, γ-BHC, and carbaryl.

Fig. 9.134. Bagrada spp. (Harlequin Bugs); Kenya.



Diploxys fallax Stål

Common name Rice Stink Bug
Family Pentatomidae
Hosts (main). Rice
(alternative). The flowers of various grass species.
Damage The adults feed on grass flowers before moving on to the rice crop for egg-laying. Adults and nymphs feed on the newly emerged florets before the milk stage of the grain, causing deformation or loss of grain.
Pest status Occasionally a serious pest of rice in Africa.
Life history About 20 eggs per female are laid in two rows on the upper leaf surface along the midrib.

The nymphs are green.

Adults are pale brown, with a pair of lateral spines on the dorsum.
Distribution Africa only; in Swaziland and Madagascar.
Control Cultural control can be achieved by eradication of grass flowers around the paddy fields so that a population build-up prior to the flowering of the rice crop is avoided.

Chemical control can be achieved by dusting with BHC, carbaryl, malathion, or trichlorphon.

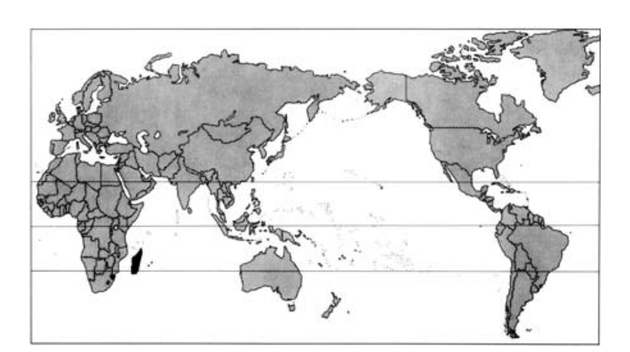
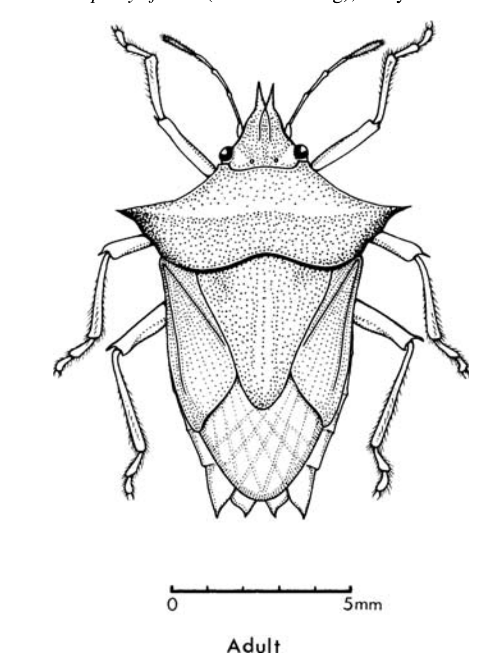


Fig. 9.135. Diploxys fallax (Rice Stink Bug); Kenya.



Nezara viridula (L.)

Common name Green Stink Bug (Green Vegetable Bug)
Family Pentatomidae
Hosts (main). Vegetables and legumes, cotton

(alternative). Many other crops and ornamentals; truly polyphagous, recorded from more than 100 different plant hosts.

Damage Toxic saliva injected at feeding causes death of tissues and necrosis; fruits and leaves become distorted and spotted; young fruits may be shed.

Pest status A common and worldwide pest, sometimes quite serious, but to be found regularly on a very wide range of crops in the warmer parts of the world.

Life history In cooler regions the adults hibernate over the winter period, amongst vegetation. They emerge in the spring, mate, and the females lay their eggs. Eggs are barrel-shaped, large (1.2 × 0.75 mm), and laid in clusters under the leaves, usually 50–60 per batch (10–130 recorded); each female lays some 100–300 eggs.

There are five nymphal instars, the first remains clustered by the egg-raft, but later ones disperse and feed from the soft parts of the plant, preferably from developing fruits and seeds. The nymphs are orange and brown in colour.

Development is generally slow; from egg to adult taking 6–10 weeks; with a pre-oviposition period of about 2–3 weeks. The threshold temperature for development is 12°C. In the eastern Mediterranean there are three generations per year.

The adult is a large green bug, about 15–18 mm long and 8–10 mm broad. Some individuals have a yellow edge to the pronotum, and some are brownish rather than green in colour, but these are not common.

Distribution Completely cosmopolitan in the warmer parts of the world, from southern Europe and Japan, to South Africa and Australasia (CIE map no. A.27).

Control *Teleonemus basalis* (Woll.) (Hym., Scelionidae) is an important egg-parasite, and has been introduced into Australia in an attempt to control this pest.

Chemical control is not often required, and is in fact difficult to achieve; chemicals used with some success include DDT, HCH, phorate, malathion, dimethoate, and phosphamidon, fenthion, azinphos-methyl, acephate, monocrotophos.

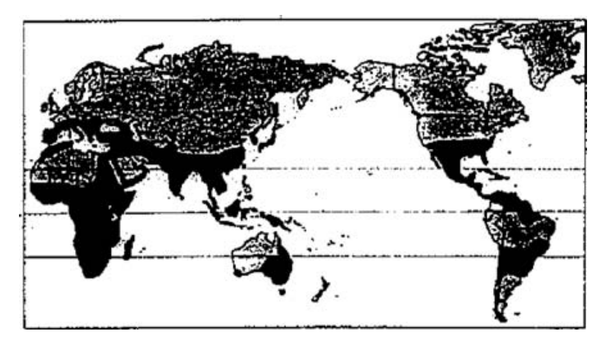
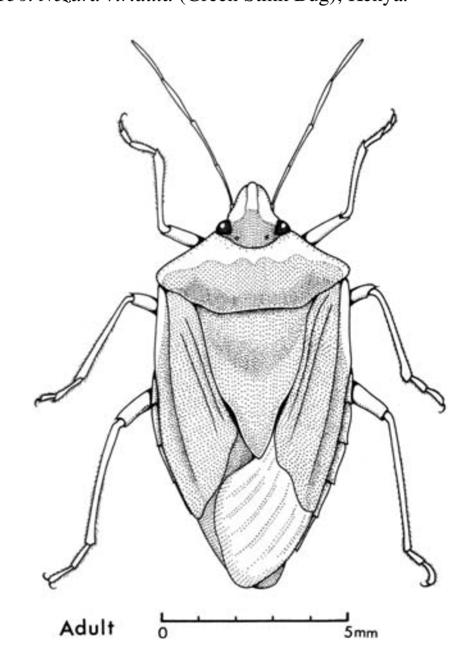




Fig. 9.136. Nezara viridula (Green Stink Bug); Kenya.



Oebalus spp.

Common name Rice Stink Bugs (Rice Seed Bug)
Family Pentatomidae
Hosts (main). Rice
(alternative). Various species of grasses, maize and sorghums.
Damage Both nymphs and adults feed on rice kernels at the milk stage, and the feeding results in the grain being infected by a fungus which enters via the bug's feeding punctures. These grains do not break during milling, and lower the grade of the rice; the condition is known as 'peckiness'. Overwintering adults emerge in early spring, and feed on developing grass seeds.
Pest status A major pest of rice in America, where yields may often be reduced by half. Four other species of *Oebalus* are recorded from rice in America.
Life history The eggs are bright green, turning red before hatching. They are 0.8 mm long and 0.6 mm in diameter, and are laid in batches of 10–47, on the stems, leaves, or panicles of rice plants or many grass species. They hatch in 4–8 days.

The nymphs are black with a red abdomen on hatching, but gradually pale during successive instars. There are five nymphal instars.

Adults are yellowish, 9–12 mm long and 5–6 mm broad. They have sharp shoulder spines pointing forwards. As with other pentatomids they emit a characteristic repugnant odour. Adults live for 30–40 days, but can hibernate in wood trash and 'bunch' grass.
Distribution *O. pugnax* is found in Southern USA, Cuba and the Dominican Republic.

Four other species of *Oebalus* are of importance on rice in S. America, and *O. poecilus* is a major pest on rice in Indonesia.
Control The use of light traps will deplete numbers of adults.

Chemicals applied just before rice flowering give adequate control. In the USA insecticidal control measures are advocated if numbers average ten bugs per hundred heads of rice. Recommended insecticides are DDT, BHC, aldrin, chlordane, malathion, carbaryl, and chlorpyrifos.

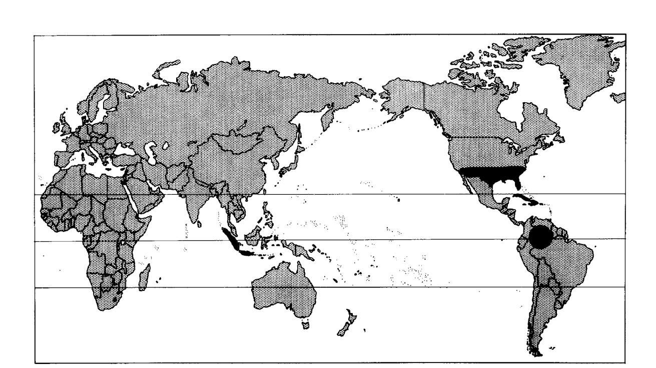
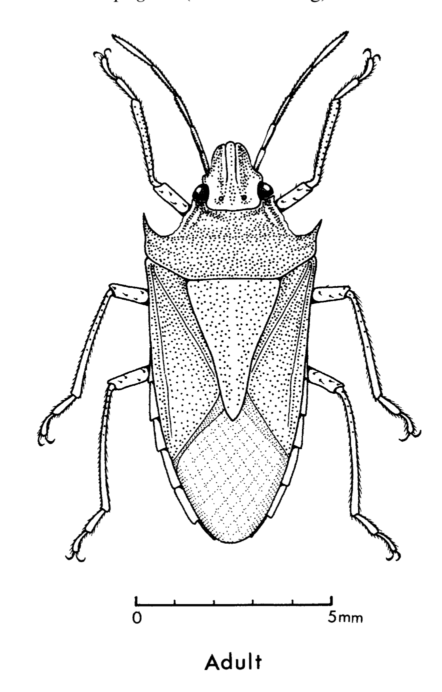


Fig. 9.137. Oebalus pugnax (Rice Stink Bug).



Rhynchocoris spp.

Common name Citrus Stink Bugs
Family Pentatomidae
Hosts *Citrus* species only to date, but probably also other Rutaceae.
Damage Adults and nymphs feed on young fruit, and usually the feeding puncture becomes infested by bacteria and fungi which causes rotting and results in premature fruit-fall. *Nematosphora* transmitted.
Pest status Quite serious pests in the north of India, the Philippines and in parts of China.
Life history Eggs (large and globular) are laid in batches of about 14, usually on the leaves, and rarely on fruit or twigs; several batches are laid per female per season. Hatching takes place after 2–9 days according to temperature. The five nymphal instars require about 30 days for development.

The adults are large shield bugs with prominent, sharp-pointed lateral expansions of the pronotum, green and brown in body colour, some 20–23 mm in body length, and with a prominent ventral keel under the thorax extending anteriorly just under the head. The pronotum is greenish, with black spots on the lateral expansions, and scutellum generally more brown; the underneath and legs are pale greenish, but the tarsi are dark, as are the distal ends of the tibiae.

There are two or three generations per year in the Philippines and in India, but only one in China; the adults hibernate in India and China over the cool winter period.
Distribution *R. longirostris* occurs in the Philippines, and *R. humeralis* in India and southern China.
The Citrus Shield Bug of Australia is *Biprolus bibax*, that of Africa is *Halydicoris ventralis*.
Control In China it was recorded that most of the egg batches are parasitized by a small chalcid wasp and so egg mortality was high, and there was extensive predation of the bugs by spiders, mantids and ants. In Guangdong the Red Tree Ant (*Oecophylla smaragdina*) has been encouraged to nest in *Citrus* orchards since ancient times, as one of the earliest recorded examples of (fairly successful) biological control.

In the Philippines chemical control is regularly practised.

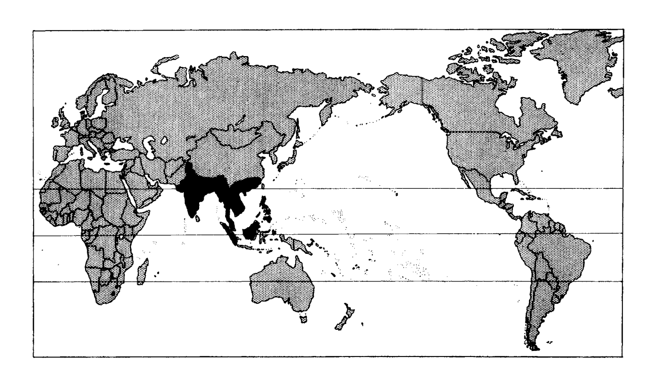
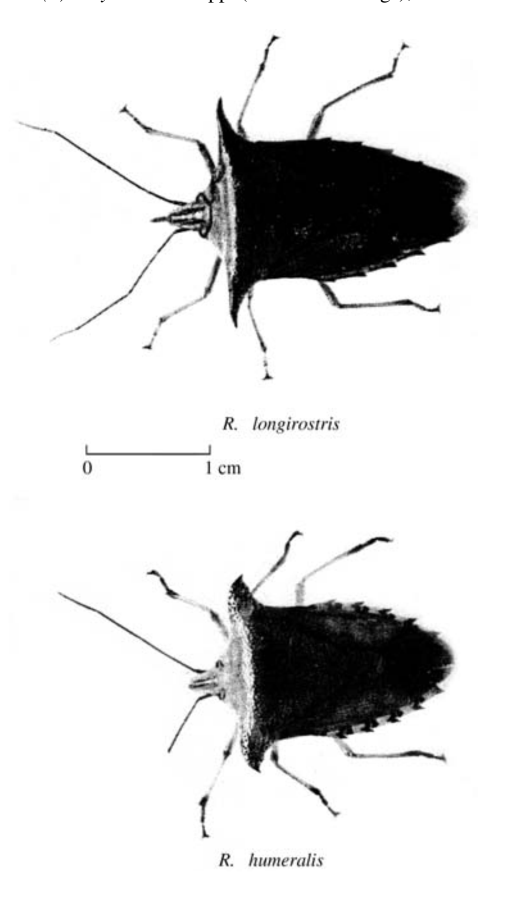


Fig. 9.138(a). Rhynchocoris spp. (Citrus Stink Bugs); S. China.



Tesseratoma spp.

Common name Litchi Stink Bugs
Family Pentatomidae
Hosts Litchi and longan only.
Damage These large bugs occur in large populations and together they remove very considerable quantities of sap by their feeding; there is often damage to new shoots in the spring. The stink fluid ejected at times of fright or trauma may cause necrotic spots on young tender leaves.
Pest status A fairly serious pest of both litchi and longan in the region from S. China down to Malaysia.
Life history Eggs are laid in a group, stuck on the the undersurface of the leaf lamina, and there are invariably just 14 in number. Incubation takes 11 or more days according to ambient temperature, and can be as long as 34 days. Nymphal development takes up to 50 days. The nymphs are often liberally coated with a white waxy substance, both dorsally and ventrally, and adults are likewise often waxy ventrally.

The adults are large brown bugs some 26–30 mm in body length, with fairly short antennae, to be found sitting in the tree foliage. They are strong fliers and if disturbed they fly off to another tree, usually emitting jets of yellow stink fluid as they depart. In China the adults apparently hibernate through the winter in groups in trees that have thick foliage, and in that country there is probably only the one generation per year.
Distribution Recorded from S. China, the Indo-China peninsula and Malaya.
T. papillosa on litchi and longan – China and S.E. Asia.
T. javanica on litchi – India, Indonesia.
T. quadrata on litchi and apple – India.
Control In China it was recorded that predation by ants and spiders was responsible for keeping populations under some control. This is supplemented by widespread hand-picking of the adults by the orchard workmen; the most successful times for hand collection was in the autumn when the bugs congregated for hibernation, and also in the spring prior to egg-laying. In Guangdong since 1964 the egg parasite *Anastatus* sp. (Hymenoptera; Eupelmidae) has been used successfully as a means of reducing the bug populations.

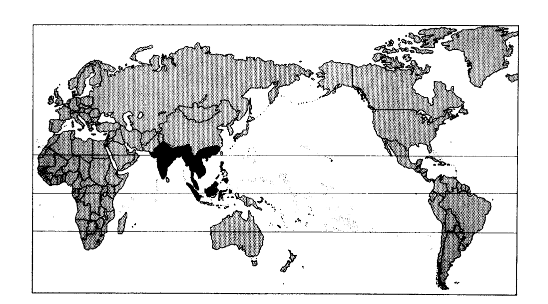
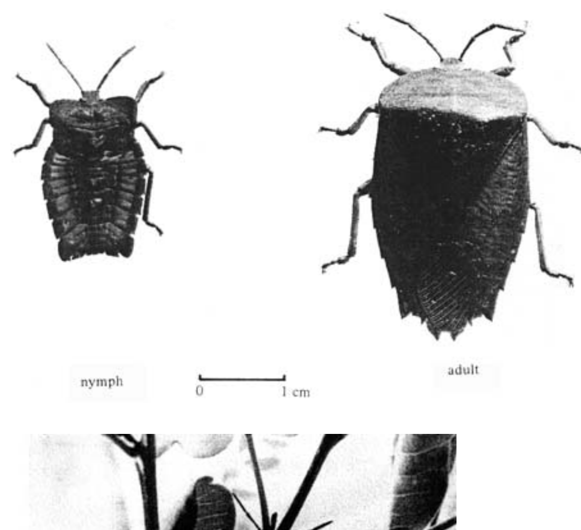
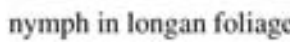


Fig. 9.138(b). Tesseratoma papillosa (Litchi Stink Bug)






nymph in longan foliage



adult in longan foliage

Calidea spp.

dregii Germar
bohemani (Stål)
etc.

Common name Blue Bugs
Family Scutelleridae
Hosts (main). Cotton

(alternative). Sorghum, sunflower, castor, citrus, and many wild hosts, including *Crotalaria, Solanum, Combretum, Hibiscus,* and *Euphorbia* spp.

Damage The adult bugs feed on developing seeds in unopened cotton bolls, with the result that development ceases and the boll aborts. The feeding of *Calidea* bugs results in the staining of the cotton lint and it appears that the bugs transmit the fungi of stigmatomycosis.

Pest status An important pest of cotton in Tanzania. Extremely polyphagous in habits, attacking the seeds of many cultivated and wild plants.

A total of five species of *Calidea* have been recorded from cotton in different parts of Africa.

Life history *Calidea* bugs seldom breed on cotton, and usually only appear on the crop when the bolls are well formed. The life history details are taken from studies of *C. dregii* on sorghum and sunflower in Tanzania.

The eggs are spherical, 1 mm in diameter, and laid in batches of up to 40 in a closed spiral round a stalk or dried leaf, or seed head, of the host plant. They are white, turning red as they develop.

The nymphs are oval and flattened, and in colour like the adults.

Adults are strikingly coloured, with red or orange underneath, and the upper surface an iri-descent blue or green, often with a bronze tinge, with a bold pattern of spots and stripes. The size range is 8–17 mm long by 4–8 mm broad.

The complete life-cycle takes from 23–56 days according to the temperature.

Distribution Restricted to the Ethiopian region, including Madagascar and Arabia. Many different species of *Calidea* are found throughout Africa, on a wide range of host plants.

Control The devastation that heavy infestations of *Calidea* can cause, and the swift and unpredictable nature of the attack, have resulted in the susceptible areas of Tanzania being avoided for cotton growing.

This pest is difficult to kill with insecticides, but the crop can be protected against combined *Calidea* and *Helicoverpa armigera* attack by repeated sprays of DDT (low volume) at weekly intervals for up to 12 weeks, or cypermethrin.

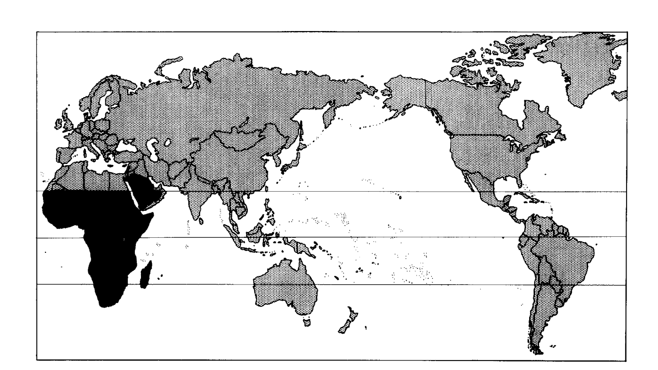
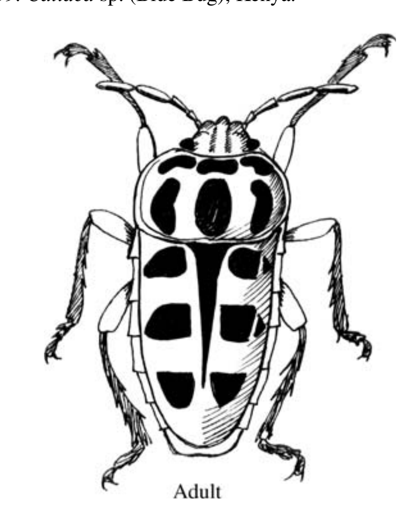


Fig. 9.139. Calidea sp. (Blue Bug); Kenya.



Scotinophara coarctata (Thunb.)

Common name Black Paddy Bug
Family Scutellariidae
Hosts (main). Rice
(alternative). *Scirpus grossus, Scleria sumatrensis,* and *Hymenachne pseudointerrupta* (Gramineae).
Damage Nymphs and adults feed at the base of stems, often just at water level. Infested plants are often stunted and grain fails to develop. Severe infestations, and very young, attacked plants, often die. The saliva of this bug is very toxic.
Pest status A pest of rice, periodically serious, in many areas.

Seven other species are found on rice in different regions.
Life history Eggs are laid in batches of 40–50; one female laying several hundred eggs. Each egg is about 1 mm long, and is green or pink. The incubation period is 4–7 days.

The young nymphs are brown with a green abdomen. They moult five times and become adult after 25–30 days. Adult female stands guard over egg mass to deter parasites.

The adult bug is 8–9 mm long, brownish-black, with a few indistinct yellow spots on the thorax. The tibiae and tarsi are pink. It can live for up to seven months, and is strongly attracted to light, often appearing in large swarms.

The life-cycle takes about 32–42 days for completion.
Distribution Pakistan, India, Bangladesh, Thailand, Malaysia, Sabah, S. China and Indonesia.
S. lurida (Japanese Black Rice Bug) is important in Japan and occurs in India, S.E. Asia and China.
Control The usual recommendation was a dust of equal parts of DDT and BHC to be applied to the plants, but pyrethroids are now used.
Egg parasitism by *Telenomus triptus* is often 20–50%.

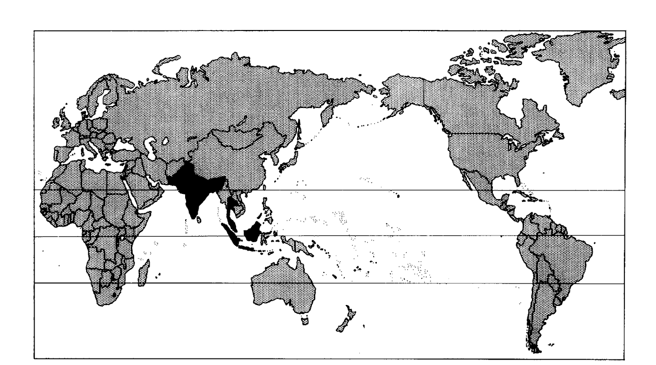
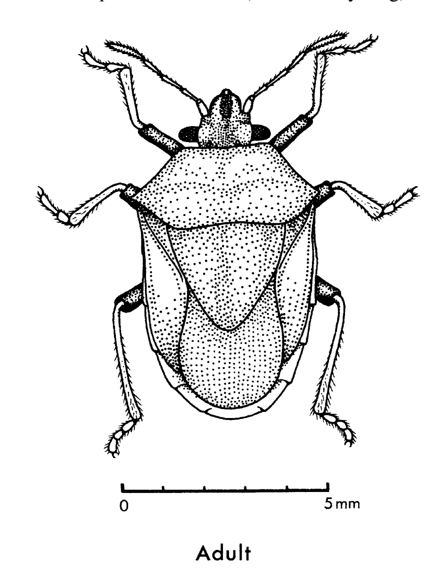


Fig. 9.140. Scotinophara coarctata (Black Paddy Bug)



Order **THYSANOPTERA**

(Thrips) Small or minute insects, with short six-segmented antennae, and asymmetrical rasping and sucking mouthparts; tarsi with one or two segments, each with a terminal protrusible vesicle. The wings are very narrow with greatly reduced venation, and long marginal setae. Metamorphosis is accompanied by one or two inactive pupal instars. Most are plant feeders but a few species are predaceous.

Suborder **TEREBRANTIA**

Family Thripidae

Most of the crop pests belong to this family within the Suborder Terebrantia; they have a saw-like ovipositor, and the apex of the abdomen is conical in the female and bluntly rounded in the male. The differences between this and the three other families tend to be rather esoteric. Many species are quite important crop pests. A striking feature of many thrips is that, whereas the adults are mostly grey, brown or black, the nymphs are typically yellow, orange or red. Thus an infested leaf may have red nymphs feeding alongside black adults. Pupation usually takes place in the soil. Damage by these thrips usually consists of scarification of the leaf lamina as a result of feeding.

Suborder TUBULIFERA

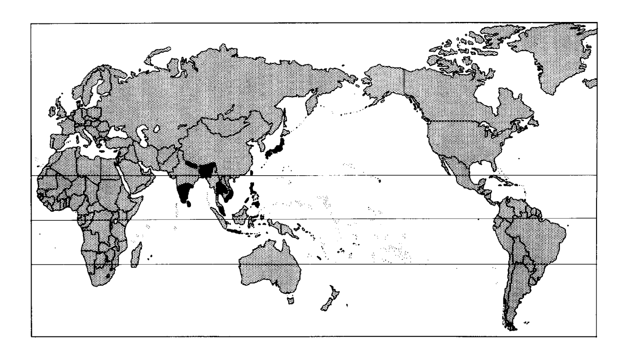
No ovipositor, and tenth abdominal segment usually tubular; wings without microtrichia, and veins either absent or only one vestigial vein present.

Family Phlaeothripidae

This large family contains over 300 genera, which show a great diversity of habits; some species are predaceous, some are fungus-feeders and are found in leaf litter and soil; most are phytophagous. The feeding of these thrips usually causes leaf-folding, leaf-rolling, or general leaf deformation to produce characteristic symptoms (or galls). Breeding takes place within the folded leaf, and in some species the adults show parental care and guard the eggs and nymphs. There are not many important agricultural pests within this family but a number of species are minor pests on various tree crops and woody ornamentals. *Hoplandothrips* is found on several trees where it rolls the young leaves. *Gynaikothrips* is common in the tropics; *G. ficorum* causes leaf-folding on *Ficus retusa* and *F. microcarpa*, and *G. kuwani* causes spectacular leaf distortion on *Aporusa chinensis. Gigantothrips elegans* is one of the largest thrips known and measures about 5 mm, and is to be found on the foliage of *Ficus* trees.

Baliothrips biformis (Bagn.)
(= *Chloethrips oryzae* (Williams))
(=*Thrips oryzae* Williams)

Common name Rice Thrips
Family Thripidae
Hosts (main). Rice
(alternative). Not known.
Damage Essentially a pest of young rice seedlings. Nymphs and adults rasp the tissues of the leaf and suck the sap that exudes. Damaged leaves show fine yellow streaks which later join together to colour the whole leaf. Later the leaves curl longitudinally from the margin to the midline; eventually the whole plant may wither. Older plants are seldom attacked – these are plants four weeks after transplanting.
Pest status Damage can be serious because of the high rate of reproduction of this pest, but only to young seedlings.



Life history Eggs are laid singly into the leaf tissues of the leaf, and they hatch in about three days. They measure 0.25 × 0.1 mm.

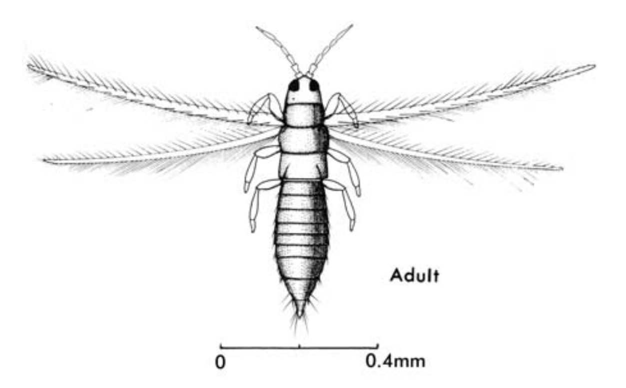
Nymphs are white or pale yellow, and remain in the young rolled leaves where they develop. There are usually four nymphal instars, the last being the resting 'pupal' stage. The nymphal period lasts for 10–14 days.

The adults are minute, about 1 mm in length, dark brown, with seven-segmented antennae. At the base of the forewing is a pale spot. The tarsi end in protrusible suckers used for attachment to leaf surfaces. The adults can live for up to three weeks.

The entire life-cycle is often not more than two weeks.
Distribution India, Sri Lanka, Bangladesh, S.E. Asia, Java, Philippines, Taiwan, and Japan (CIE map no. A215).
Control Removal of all infested leaves in seedbeds, is recommended.

Contact insecticides which have proved effective are carbaryl, DDT, BHC, malathion, diazinon. Dimethoate with its systemic action is highly effective.

Fig. 9.141. Baliothrips biformis (Rice Thrips).



Thrips (Order Thysanoptera)

A large worldwide group with at least 5000 species, well represented in the tropics but most abundant in temperate regions where their extensive summer dispersal flights earn them the name of 'thunder-flies'.

Many species are phytophagous and feed on the leaves of their host plants, but some infest flowers and affect fruits, and a few make galls. A few are predacious and eat other insects, and many are fungus-feeders and to be found in leaf litter. Some of the phytophagous species are polyphagous as well as cosmopolitan, but others are more restricted in their diets and distributions. Some species are important as vectors of virus diseases, especially some of those that occur in glasshouses in Europe and N. America.

Adults are generally black or brown in colour, and most are quite similar in appearance, so field identification is very difficult in most cases. Reliance on host plant data usually gives a good indication as to identity. The nymphs are often red, orange, or yellow in colour in contrast to the drab adults. Pupation almost always takes place in the soil; *Heliothrips haemorrhoidalis* is unusual in that pupation takes place on the host plant.

Pest species occur in the two largest families. The Thripidae are almost all sap-feeding and there are over 160 genera. Eggs are inserted into the host plant tissues using the saw-like ovipositor. Most of the pest species belong to this family. The Phlaeothripidae contains over 300 genera and a few are pests by their actions of leaf-rolling and leaf-distortion. In some species the adults guard the egg-mass on the leaf surface, and also remain with the nymphs after hatching.

Important pest species of thrips

In addition to the species already mentioned in this chapter, the following are species of some importance as crop pests, and most of them are temperate in distribution.

Phlaeothripidae

Gigantothrips elegans – (Giant Fig Thrips) on leaves of *Ficus*; Asia.

Gynaikothrips ficorum – (Banyan Leaf-rolling Thrips) on *Ficus retusa* (California) and *F. microcarpa* (tropical Asia).

Gynaikothrips kuwani – (Cuban Laurel Thrips) on several plants; Asia and USA.

Haplothrips leucanthemi Schrank – (Clover Thrips) Canada.

Haplothrips tritici – (Wheat Leaf-rolling Thrips) on wheat; Europe.

Hoplandothrips spp. – Coffee Leaf-rolling Thrips, etc.; Africa

Liothrips oleae – (Olive Thrips) Mediterranean Region.

Liothrips spp. – many ornamentals; USA, Asia.

Thripidae

Anaphothrips obscurus (Mull.)–(Grain Thrips) on cereals; Canada, USA and Japan.

Aptinothrips rufus (Gmel.)– on oats, barley and

Aptinothrips stylifer (Trybom) – wheat; in Europe, Canada and USA.

Aptinothrips spp. – (grass thrips) on grasses and cereals; Europe, Canada, USA.

Baliothrips biformis (Bagnall) – (Rice Thrips) on rice; tropical Asia, Taiwan, and Japan (also UK, Romania, Brazil) (CIE map no.A.215).

Baliothrips minutus (van Dev.)–(Sugarcane Thrips) USA.

Caliothrips spp. – on cotton and many other hosts in the tropics.

Hercinothrips bicinctus (Bagnall) – (Banana Thrips) on bananas in tropics and greenhouse crops in UK, Europe and USA.

Hercinothrips femoralis (Reuter) – (Banded Greenhouse (Sugarbeet) Thrips) polyphagous on field crops and ornamentals in greenhouses; cosmopolitan (CIE map no. A.402).

Limothrips cerealium (Halstead) – (Grain Thrips) wheat, maize, rye, oats, barley, grasses and citrus; cosmopolitan (CIE map no. A.245).

Limothrips denticornis (Halstead) – (Barley Thrips) on cereals; Canada.

Scirtothrips aurantii Faure – (Citrus (Tea) Thrips) polyphagous; from Egypt and Africa (CIE map no. A.137).

Selenothrips rubrocinctus (Giard) – (Red-banded Thrips) polyphagous; pantropical (CIE map no. A.136).

Taeniothrips inconsequens (Uzel) – (Pear Thrips) in flowers of pear, plum, apple; Europe and USA.

Taeniothrips simplex (Morison) – (Gladiolus Thrips) Europe; on Liliaceae.

Taeniothrips sjostedti (Trybom) – (Bean Flower Thrips) polyphagous in flowers; Malta and Africa.

Control of thrips

Parasitic Hymenoptera are of some importance, especially some species of Eulophidae.

Ploughing after crop harvest will help to kill pupae in the soil and adults hiding in leaf litter.

Early planting helps to avoid some seeding infestations. Chemical application as a means of virus control is generally unsuccessful. For chemical control of the thrips themselves the following treatments are recommended:

(1) Soil application of DDT or HCH, or granules of aldicarb or phorate.

(2) Foliar sprays of DDT, carbaryl, fenitrothion, or dimethoate.

(3) In glasshouses use smokes or fogs of DDT, HCH, parathion, nicotine or pirimiphos-methyl; or sprays of diazinon, dichlorvos or resmethrin.

(4) A recent trend in the UK, as part of the general biological control programmes in commercial glasshouses, is to spray a special formulation of deltamethrin and polybutene ('*Thripstick*') on to the floor covering to kill the thrips as they fall to the ground to pupate.

An extensive list of insecticides, dosages and methods of application, effective against thrips (but somewhat out of date now), is given as appendix 5 in Lewis (1973), pages 310–312.

Diarthrothrips coffeae Williams

Common name Coffee Thrips
Family Thripidae
Hosts (main). *Coffea arabica*.

(alternative). Only one wild host is definitely recorded (a *Vanguoria* sp.) but the Coffee Thrips can almost certainly breed on a large number of plants.

Damage Undersides of leaves, and in severe cases the upper sides of leaves, berries and green shoots, with irregular grey or silvery patches covered by minute black spots. Death of leaves and total leaf-fall may follow a very heavy infestation.

Pest status Up to about 1950, severe outbreaks occurred on *arabica* coffee in Kenya about every fourth year in the hot weather of February and March. Since then there have only been relatively isolated outbreaks and few of outstanding severity.

Life history Eggs are minute kidney-shaped objects inserted into the tissues of the leaf.

There are two nymphal stages. The nymphs are cigar-shaped tiny insects, pale yellow, and just visible to the unaided eye; found on the undersides of the leaves.

At the end of the nymphal period, the nymphs drop to the ground and in an earthen cell change into pre-pupae. These then change into pupae from which the adult thrips finally emerge.

Adults crawl out of the soil, fly back into the tree and feed with the nymphs. They can be distinguished from the nymphs by their slightly larger size (1.5 mm), their grey-brown colour and their feather-like wings.

In hot weather one generation probably takes about three weeks.

Distribution E. Africa, Malawi, and Zaïre.

Control Mulching reduces thrips numbers considerably and its widespread use in recent years is probably a reason for the declining importance of this pest.

Insecticides such as fenitrothion, chlorpyril and fenthion give effective thrips control; but the best chemical is dictrotophos, to be used in a dry season if the population exceeds two per leaf (adults plus nymphs).

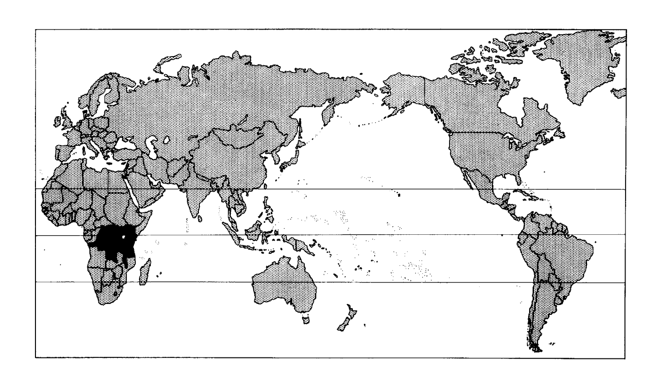
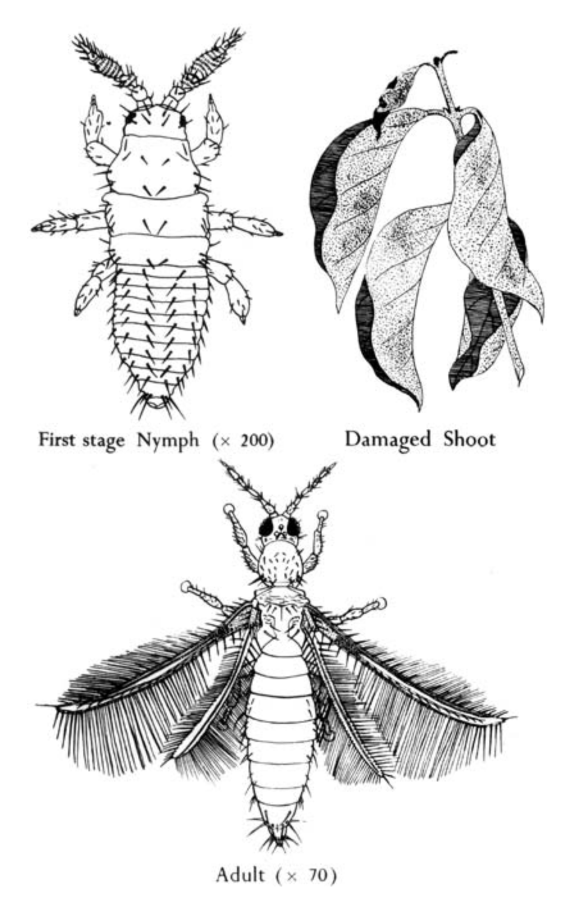


Fig. 9.142. Diarthrothrips coffeae (Coffee Thrips); Kenya.



Frankliniella schulzei (Trybom)

Common name Cotton Bud Thrips (Flower Thrips)
Family Thripidae
Hosts (main). Groundnut, beans, cotton.

(alternative). A polyphagous pest on many crops and flowers, including coffee, sweet potato, and tomato.

Damage Adults and nymphs feed in flowers and on leaves of many plants, especially legumes. They rasp the cells off the upper surface of young leaves while they are still in the bud, and these leaves become distorted. Seedling growth may be retarded by several weeks, and yield can be seriously affected. Mature plants are little affected by thrips.

Pest status Various species of thrips are pests of some importance on groundnut, beans and other legumes in many parts of the world. Sometimes, although the thrips are common in the flowers, no actual damage is done. This species is a vector of Tomato Spotted Wilt virus on groundnuts; in Australia yield decreases of 90% have been recorded. This virus is widespread in groundnut growing areas but generally of low crop incidence (usually less than 5%).

Life history Eggs are laid in the leaf tissue.

Nymphs are pale-coloured and wingless, and found under the curled leaves. There are three instars.

Pupation takes place in the soil.

The adults are pale brown, dark brown or black, with paler bands across the abdominal segments, and 1.0–1.5 mm long.

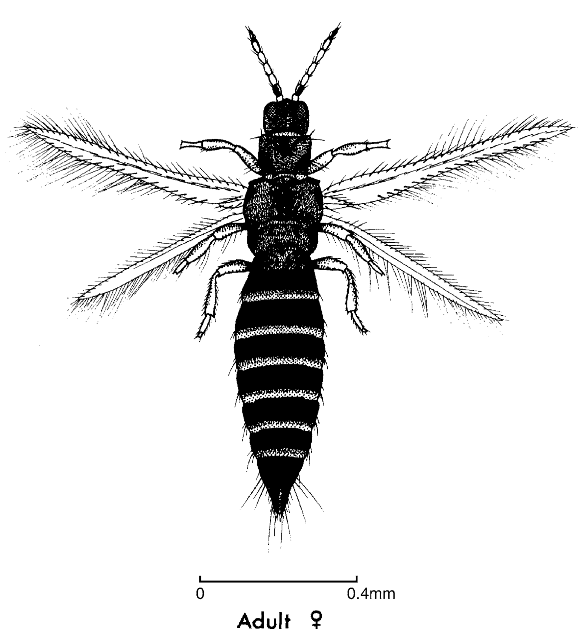
The life-cycle usually takes about 2–5 weeks, so that in hot, dry conditions damage may be apparent quite suddenly.

Distribution E. Africa and the Sudan.

Several other species of *Frankliniella* are found on a similar range of host plants, in Africa, Asia, and America; the genus is cosmopolitan.

Control Both contact and systemic insecticides have been used successfully against thrips on groundnut, including: DDT and BHC dusts and sprays, malathion, phorate dust, and dimethoate sprays. Fenitrothion, fenthion and chlorpyrifos are also effective and widely used now.

Fig. 9.143. Frankliniella schulzei (Flower Thrips)



Heliothrips haemorrhoidalis (Bouché)

Common name Black Tea Thrips (Greenhouse Thrips)
Family Thripidae
Hosts (main). Tea

(alternative). A wide range of cultivated plants including roses, coffee, bananas, *Citrus*.

Damage Silvery patches covered by black spots on the undersides of the older leaves.

Pest status A polyphagous pest attacking many plants, and found in greenhouses in temperate climates. Only sporadically serious on tea in E. Africa.

Life history The eggs are bean-shaped, about 0.3 mm long, and are pushed into the leaf tissue by the female, the wound being covered by a spot of excreta.

The first stage nymph is white, with red eyes, and just visible to the unaided eye. It rasps and sucks at the leaf surface causing the characteristic silvery patches by removing chlorophyll from the leaf tissue and letting air into the surface cells. The nymph carries a shining drop of greenish brown or black excreta on the tip of its upturned abdomen. It deposits these drops at intervals, causing the black spots on the leaves. The nymphs usually congregate on a damaged leaf and first change to a 'pre-pupal' stage with short wing pads; after a day or two they moult again into the 'pupal' stage which has rather longer wing pads. Both stages are yellow in colour with red eyes.

The adult thrips is dark brown or black, with whitish legs, antennae and wings. When the wings are folded they appear as an elongate T-shaped mark down the middle of the back. The Black Tea Thrips is one of the larger thrips, being about 1.5 mm long. All adults are females, which reproduce partheno-genetically. Each female lays some 25 eggs over a seven week period.

The total life-cycle takes from eight weeks at 19°C to 12 weeks at 15°C.

Distribution This is a cosmopolitan species occurring in temperate countries in greenhouses; however records are sparse from Asia (CIE map no. A135).

Control The usual insecticide employed against this pest is fenitrothion, as a full-cover spray directed as far as possible at the underside of the leaves.

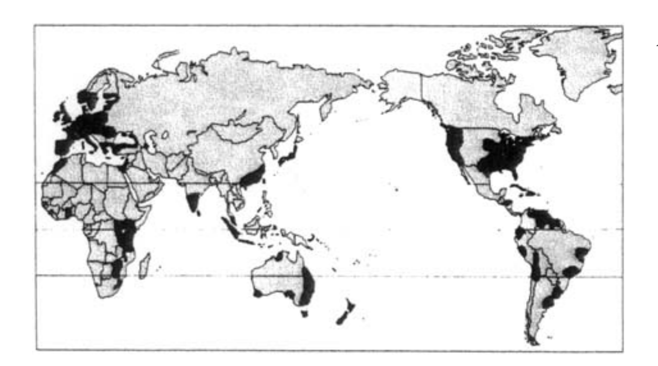
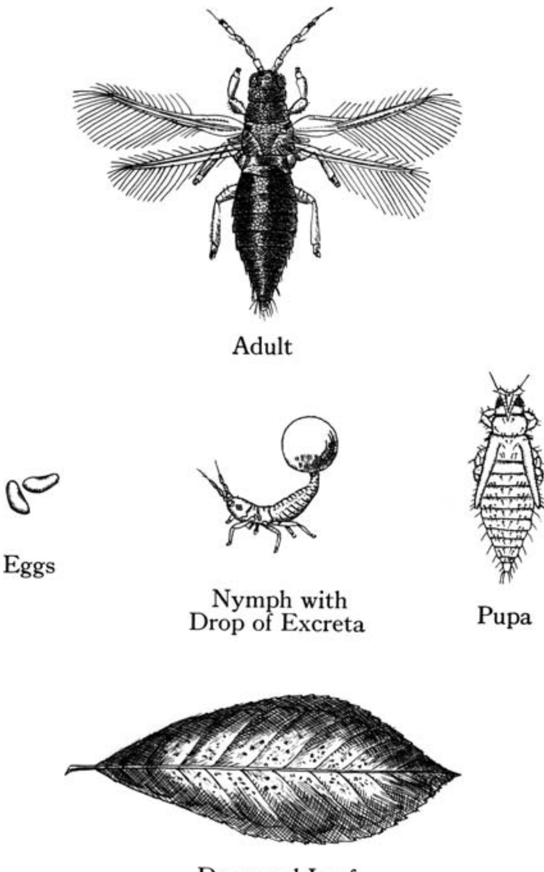


Fig. 9.144. Heliothrips haemorrhoidalis (Black Tea Thrips); Kenya.



Hercinothrips bicinctus (Bagnall)

Common name Banana Thrips
Family Thripidae
Hosts (main). Bananas

(alternative). None are recorded in Africa but several greenhouse crops are attacked in Europe.

Damage Silvery or brown patches covered with small black spots found on the fruits. The skin of severely infested fruit may crack, and this allows secondary rots to attack the fruit.

Pest status A serious pest of bananas if high-grade fruit is being produced. The damage is, however, often only a skin blemish and is of little significance on the local market.

Life history Eggs are inserted into the plant tissues; a favoured site appears to be on the fruit surfaces where two young bananas are in close contact.

Nymphs are yellowish but the abdomen may appear black and swollen due to the presence of liquid excreta. A globule of excreta is also carried at the upturned tip of the abdomen. A full-grown nymph is over 1 mm long.

The so-called pupal stages probably occur in the soil.

The adult is a fairly large thrips about 1.5 mm long, and is dark brown.

Distribution Africa, and S. Europe, Australia, Hawaii, N. and S. America, and the W. Indies. (CIE map No. A.457).

Control The following insecticides are generally effective against this pest: fenitrothion, fenthion and phosphamidon.

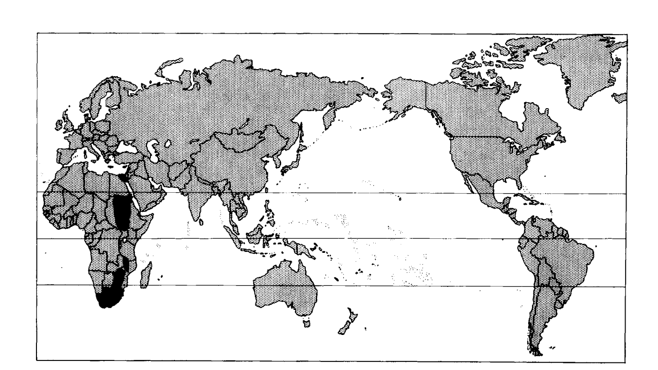
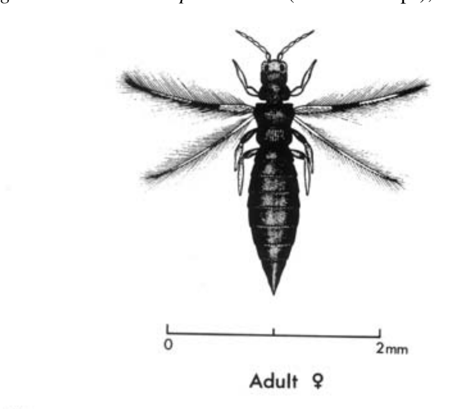
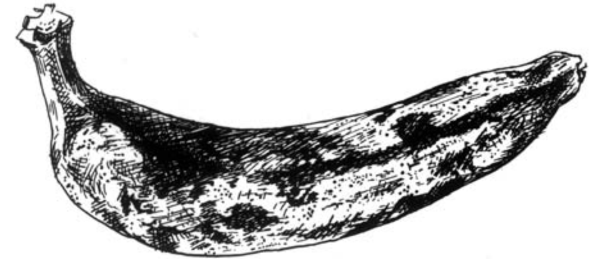
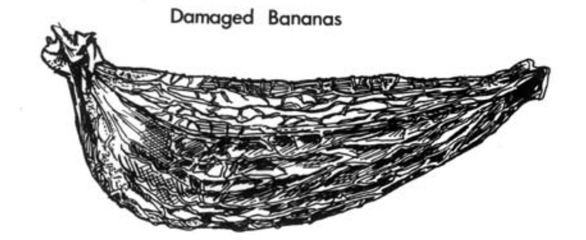


Fig. 9.145. Hercinothrips bicinctus (Banana Thrips); Kenya.







Scirtothrips aurantii Fauré

Common name Citrus Thrips
Family Thripidae
Hosts (main). *Citrus* spp.
(alternative). Over thirty indigenous trees and shrubs have been recorded in S. Africa.
Damage A ring of scaly, brownish tissue round the stem end of the fruit. Irregular areas of scarred tissue on other parts of the fruit. Young leaves may be damaged.
Pest status A serious pest at low altitudes where an attempt to produce unblemished fruit is being made.
Life history The egg is bean-shaped, very small (less than 0.2 mm long) and inserted into the soft tissues of leaves, stems and fruit. Hatching takes 1–2 weeks.

There are two nymphal stages; they are yellow to orange, cigar-shaped and just visible to the unaided eye. They feed on young fruits from petal-fall until they are about 25 mm in diameter. Most feeding takes place at the stem end, under and near the 'button'. In the absence of suitable fruits young leaves may be attacked. The nymphal period lasts 8–15 days.

When fully grown, nymphs seek out some sheltered place and then pass through two resting stages called 'pre-pupa' and 'pupa' respectively. They do not feed during these stages, but may walk a little if disturbed. The pupal stages last 1–2 weeks.

The adult thrips is reddish-orange, less than 1 mm long and like all thrips has feather-like wings. Males are rare and the females probably normally reproduce parthenogenetically. Adults may live for several weeks.
Distribution Only known from Africa; Egypt, Malawi, Sudan, E. Africa, Zimbabwe, and S. Africa; most common in S. Africa (CIE map no. A137).

Another species (*S. citri*) occurs on *Citrus* in California. *Scirtothrips dorsalis* is the Chilli Thrips and is widespread throughout India, S.E.Asia down to Queensland and up to China and Japan – it is quite polyphagous on many crops (CIE map no. A475).
Control Spray the fruits towards the end of a main flowering period, when three-quarters of the petals have fallen, using a water solution of lime-sulphur. The spray should be repeated after about ten days.

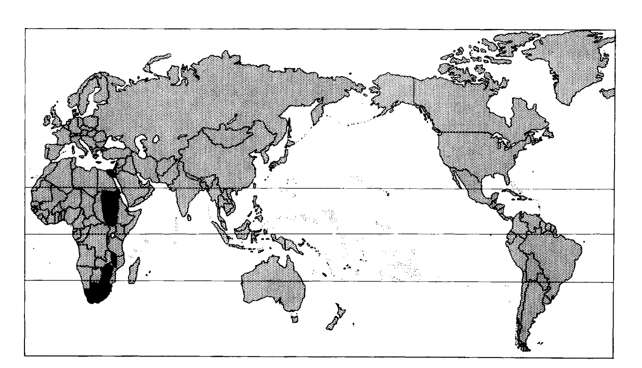
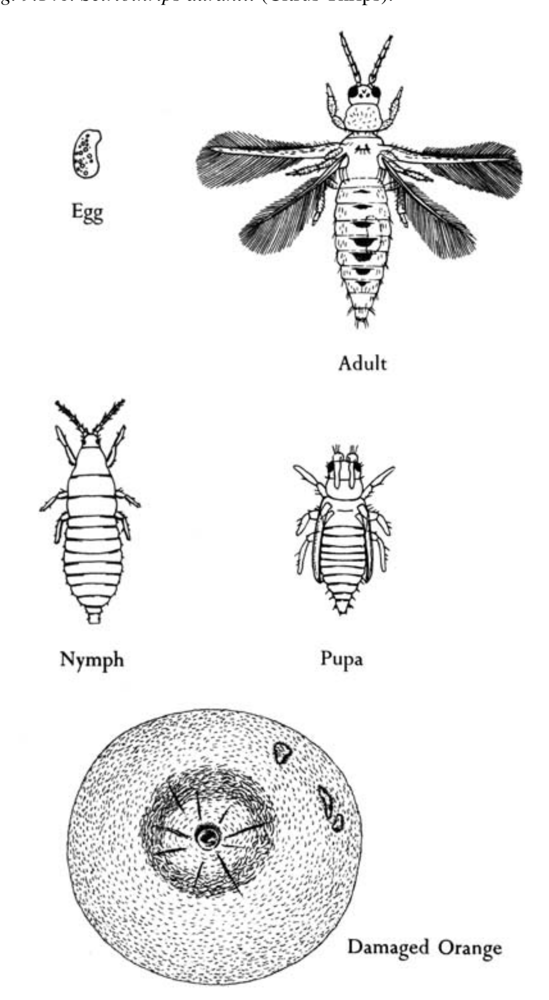


Fig. 9.146. Scirtothrips aurantii (Citrus Thrips).



Selenothrips rubrocinctus (Giard)

Common name Red-Banded Thrips (Cacao Thrips)
Family Thripidae
Hosts (main). Mango
(alternative). Avocado, pear, cashew, guava, and cacao, but usually only severe on mango.
Damage The lower leaf surfaces are darkly stained, rusty in appearance, and with numerous small, shiny black spots of excreta; leaf edges are curled.
Pest status A sporadically serious pest in mango nurseries; very rarely damaging to mature trees. A polyphagous pest of wide occurrence.
Life history The eggs are kidney-shaped, about 0.25 mm long, and are inserted into the leaf tissue by the female thrips. Hatching takes about 12–18 days.

The nymphal stages are yellow with a bright red band round the base of the abdomen. The full-grown second-stage nymph is about 1 mm long. Nymphs feed in company with the adults, normally on the underside of the leaf; depressions or grooves adjacent to the main veins are favoured sites. The tip of the abdomen is turned up and carries a large drop of reddish excreta. These drops are deposited at intervals on the leaf surface and dry to form shiny black spots. The total nymphal period lasts 6–10 days.

The so-called pupal (i.e. non-feeding) stages are passed on a sheltered spot in the curl of a leaf. Both the pre-pupal and pupal stages resemble the nymphs but differ in having well-developed wing buds. The pupal stages can move but do not do so unless disturbed. After 3–6 days adults emerge from their pupal skins.

The adult thrips are dark brown and just over 1 mm long. Males are rare. Adults feed in company with the nymphs.
Distribution Almost completely pantropical in distribution, but not recorded from Australia (CIE map no. A136).
Control The recommended insecticide is fenitrothion as a spray directed at the undersides of the leaves.

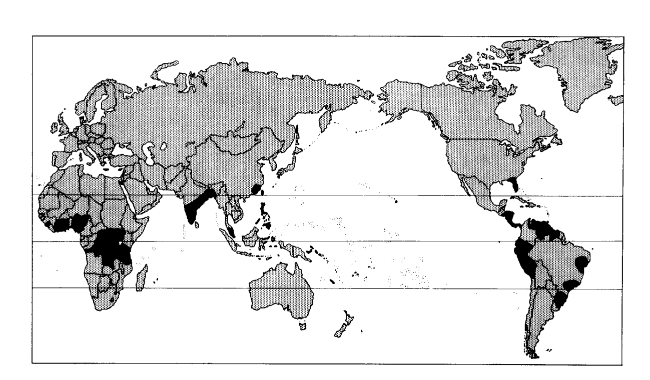
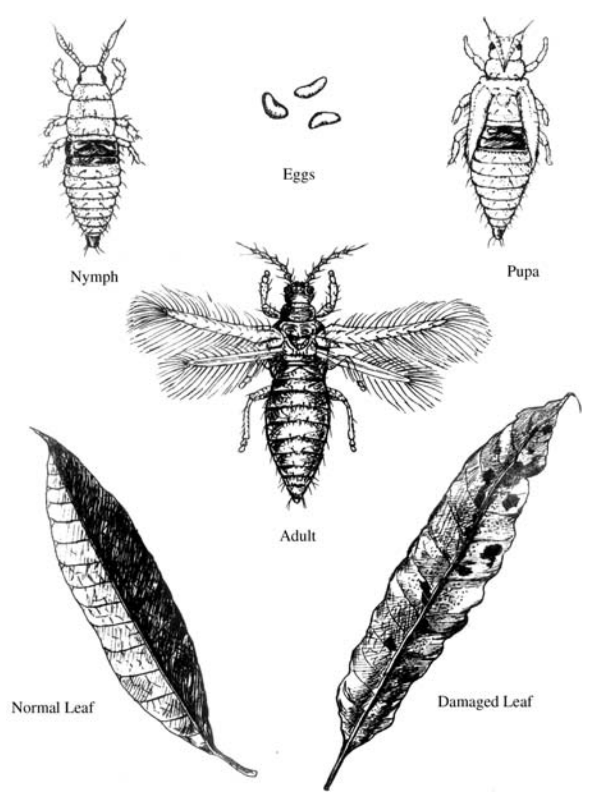


Fig. 9.147. Selenothrips rubrocinctus (Red-Banded Thrips); Kenya.



Taeniothrips sjostedti (Trybom)

Common name Bean Flower Thrips
Family Thripidae
Hosts (main). Beans, peas, groundnut.
(alternative). Coffee, avocado, and many other plants.
Damage Both adults and nymphs are found inside the flowers of beans, other legumes, and other plants. Feeding punctures can be seen at the base of the petals and stigma. In Uganda an average of three thrips per bean flower was found.
Pest status Although this thrips is commonly found in the flowers of beans and other legumes in many parts of Africa, the evidence of Ingram (1969) suggests that no real damage is done, since killing the thrips does not result in a yield increase.
Life history The eggs are presumably laid in the flowers, but this observation has not actually been made. However, first and second stage nymphs can usually be found in the flower.

Pupation occurs in the soil.

Males were not found in Uganda, and it is assumed that breeding was parthenogenetic.

The entire life-cycle takes 10–14 days.

Distribution Found only in Malta and Africa; Gambia, Ivory Coast, Nigeria, Cameroons, Central African Republic, Zaïre, E. Africa, southern Africa.

Another species (*T. distalis*) is a pest of groundnut flowers and leaves in India. *T. simplex* is the Gladiolus Thrips, and *T. laricivorous* is the European Larch Thrips. Other species are found on coffee either feeding on rust spores or the leaves.

Control Spraying with DDT and γ-BHC effectively controlled the thrips, but in Uganda control of the thrips did not result in a yield increase.
See page 257 for control suggestions.

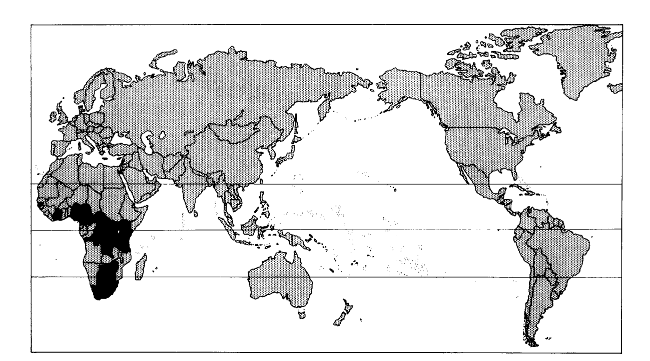
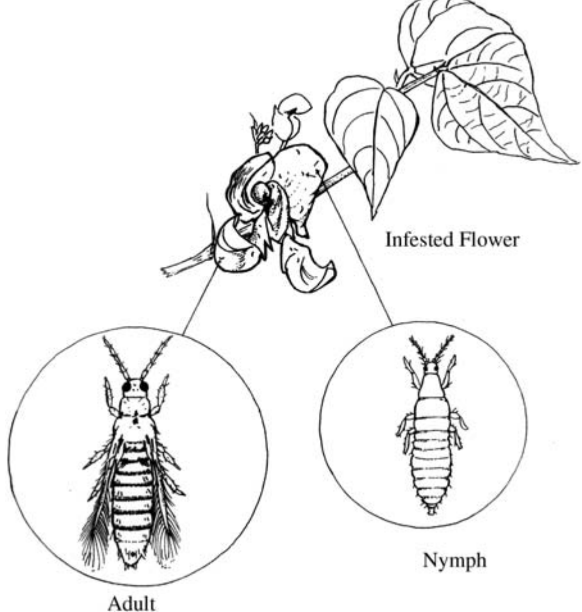


Fig. 9.148. Taeniothrips sjostedti (Bean Flower Thrips); Kenya.



Thrips tabaci Lind.

Common name Onion Thrips
Family Thripidae
Hosts (main). Onions and leek
(alternative). Tobacco, tomato, pyrethrum, cotton, pineapple, peas, brassicas, beet and many other plants.
Damage The leaves of attacked plants are silvered and flecked. Heavy attacks lead to the wilting of young plants. On cotton seedlings damage can be more serious causing leaf shedding. Onion leaves are often distorted, and sometimes they die; occasionally entire crops may die.
Pest status A polyphagous pest on many crops; vector of virus diseases of tobacco, tomato, pineapple, and other crops.
Life history Eggs are laid in notches in the epidermis of the leaves and stems of young plants. They are white, and take 4–10 days to hatch.

Both nymphs and adults rasp the epidermis of the leaves and suck the sap that exudes. Nymphs moult twice in about five days; they are white or yellow.

Pupation occurs in the soil, and takes 4–7 days.

The adult is a small, yellow-brown thrips, with darker transverse bands across the thorax and abdomen, and about 1 mm long. Long-lived 3–11 weeks.

One generation can take place in about three weeks. There are generally several generations per year, but there may be more (5–10) in the tropics.
Distribution Almost completely cosmopolitan, but only a few records are from W. Africa; the range extends from Canada and S. Scandinavia (60°N) to S. Africa and New Zealand (CIE map no. A20).
Control See page 257.

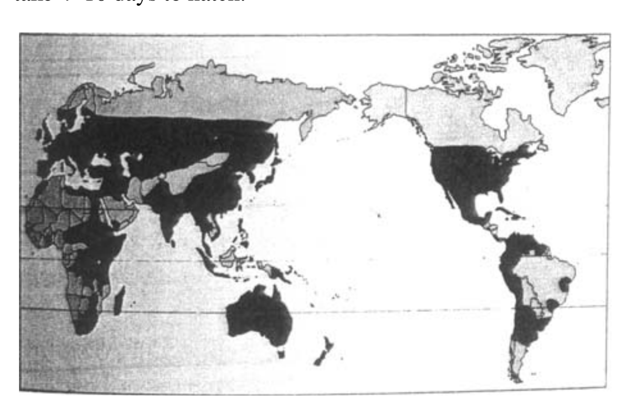
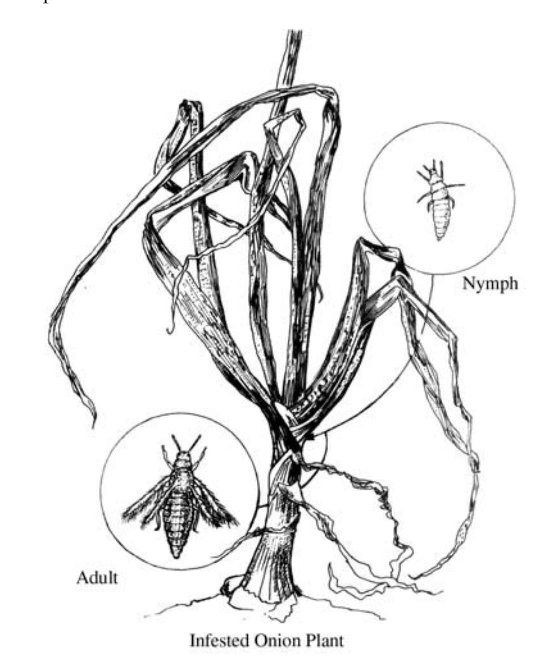




Fig. 9.149. Onion Thrips; *Thrips tabaci* and infested onion plants; Ethiopia.





Hoplandothrips marshalli Karny

Common name Coffee Leaf-rolling Thrips
Family Phlaeothripidae
Hosts (main). Coffee
(alternative). Not known
Damage Infested leaves curl upwards into a roll in which the thrips live and feed. Infestations are more common under shade, where occasionally a tree will have many curled leaves.
Pest status This is usually only a minor pest of coffee, and mainly confined to Uganda. Many species of thrips (20 or more) are recorded from coffee but very few are serious pests; in fact some species are almost certainly predators of other thrips.
Life history Most of the life-cycle is spent inside the rolled leaves, although presumably the pupal stages are spent in the soil.

The nymphs are pale yellow, and the adults are dark brown. The details of the life-cycle of this pest are not well known.
Distribution E. Africa (Kenya, Uganda, and Tanzania).

Two other species curl coffee leaves in Tanzania and Zaïre.
Control Not usually required, but occasional severe attacks have been controlled with dimethoate.

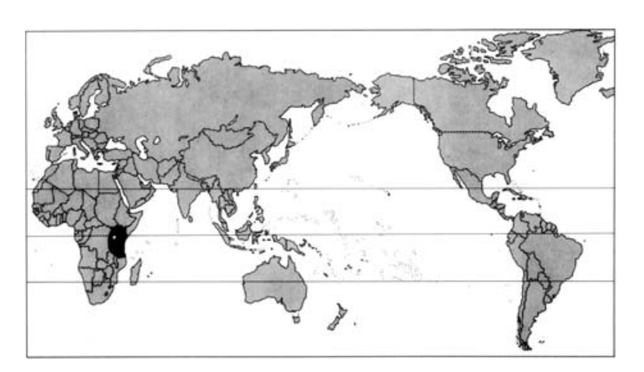
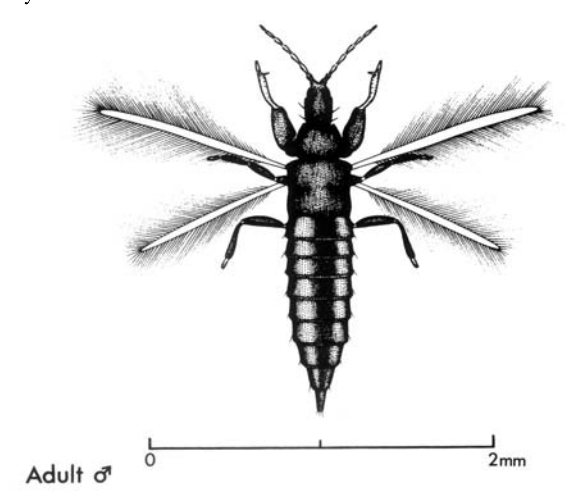


Fig. 9.150. Hoplandothrips marshalli (Coffee Leaf-rolling Thrips); Kenya.





Order **COLEOPTERA**
These are the beetles; characterized by having forewings which are thickened and hardened into elytra, and which are used to protect the delicate, folded hindwings. They range in size, from minute to gigantic insects, and this is the largest order in the animal kingdom, numbering some 220 000 species. The group exhibits great diversity of form and habits.

Family **Scarabeidae**
(Chafers or White Grubs) A very large family of over 19 000 species, which falls into several distinct subfamilies. The larvae of all are very similar in general appearance, and differ mainly in size. They are fleshy grubs with a swollen abdomen, usually adopting a C-shaped position, a well-developed head capsule and large jaws, and thoracic legs. This shape is known as 'scarabeiform'. The larvae live in the soil and rotting vegetation, and eat plant roots; many are important pests known as Chafer Grubs and White Grubs.

Subfamily **Cetoninae**
(Rose Chafers) These beetles have a flattened body, and the elytra are incurved level with the hind legs; in flight the elytra are raised slightly and the wings protrude through these emarginations. Diurnal in habits; weak mouthparts so usually feed on pollen, nectar and liquids (over-ripe fruits). Adults usually not pests (*Protaetia, Cetonia,* etc.).

Subfamily **Coprinae** (= Scarabaeinae)
(Dung Beetles) These black, rounded beetles are not pests, and neither are their larvae, but are common in pasture lands.

Subfamily **Dynastinae**
(Elephant and Rhinoceros Beetles) Large, black beetles usually; typically tropical rain forest species; the adults do some leaf-eating but are usually not pests, except for *Oryctes* spp. The spectacular *Xylotrupes* belongs to this group. Nocturnal in habits.

Subfamily **Melolonthinae**
(Cockchafers) Dull brown beetles with fat, rounded bodies; nocturnal; elytra held vertically in flight; claws of hind legs of equal size and not movable. Larvae are often serious soil pests eating roots; adults have strong mouthparts and eat leaves, and sometimes young fruits. Genera include *Melolontha, Serica, Holotrichia, Leucopholis,* and *Dermolepida*.

Subfamily **Rutelinae**
(Flower Beetles and June Beetles) The body is smooth, oval, shiny, and sometimes brightly metallic; the hind legs have thickened tibiae and long movable claws of unequal size. They are nocturnal and will fly to lights at night. Adults have well-developed mouthparts and may defoliate crops and ornamentals, eating both leaves and flowers. Common genera that are pests include *Adoretus, Anomala* and *Popillia*.

Family **Buprestidae**
(Jewel Beetles and Flat-headed Borers) Essentially a tropical group with larvae that bore tree trunks and branches; a few are temperate. The adults are oval, often brightly coloured with metallic sheen. The larvae are legless and have an expanded flattened prothorax; they usually bore in the sapwood under the bark but also make deep tunnels. Pests of timber and trees. *Agrilus* has about 700 spp. and some are pests of fruit and ornamental trees; *Chrysobothris* has about 300 spp. worldwide.

Family **Dermestidae**
(Carpet and Hide Beetles) A small family (700 spp.) of small beetles that infest animal cadavers and dried animal products, furs, carpets, etc. *Trogoderma* is a very important pest of stored cereals and is the only phytophagous member of the family.

Family **Anobiidae**
(Timber Beetles) These are pests of timber and stored products – some 1100 species have been described. The larvae tunnel in the timber, or eat the foodstuffs. Pupation usually takes place in the wood. The head of the adult beetle is deflexed under the anterior edge of the prothorax.

Family **Ptinidae**
(Spider Beetles) A small group (about 700 spp.) of stored products pests; mostly tropical; body shape is rounded and the legs rather long, which gives them a characteristic shape.

Family **Bostrychidae**
(Black Borers) A family of cylindrically shaped beetles, making cylindrical burrows in felled timber, dried wood, or occasionally standing trees. The head is bent down and hidden by the projecting prothorax. Most of the damage is done by the boring adults, and breeding takes place in the tunnels made by the adults.

Family **Lymexylidae**
A small tropical family (40 spp.); adults have a soft elongate body (especially *Atractocerus*) some with reduced elytra; larvae bore living trees and palms. Some temperate species.

Family **Nitidulidae**
A large family (2200 spp.) of small beetles of varied habits and habit; on flowers, fungi of decaying material. Some stored products pests.

Family **Silvanidae**
A small family with clubbed antennae, found mostly on plants or on plant material in storehouses. Only a couple of species are pests, and these are pests of stored products.

Family **Coccinellidae**
(Ladybird Beetles) A large family of 5000 species, mostly brightly coloured, of medium size and convex shape. The vast majority are carnivorous, being predators of aphids, coccids, and other soft-bodied insects and are of great importance in the natural control of many pests. One genus (and recently a second has been split off) is of considerable importance in being phytophagous and a pest on several different crops this is *Epilachna*.

Family **Tenebrionidae**
A large family of some 10 000 species, with larvae of striking similarity but adults exhibiting a wide diversity of form. Many are ground beetles rather like the Carabidae. Some are stored products pests, and a few species are damaging to small trees and bushes by ring-barking them.

Family **Meloidae**
(Blister Beetles; Oil Beetles) An intersting group of beetles, numbering 2000 species, with soft bodies, long legs, a deflexed head on a narrow neck. The larvae exhibit hypermetamorphosis and are predators upon the egg-pods of grasshoppers and locusts. The beetles contain a substance known as cantharidin, which is the blistering material possessed by these beetles.

Family **Cerambycidae**
(Longhorn Beetles; Longicorn Beetles) A large family of 15 000 species, of elaborate form, and attractive coloration, often of very large size. The larvae bore in timber, but a few are confined to the roots or pith of herbaceous plants.

Family **Bruchidae** (= Lariidae)
Over 1000 species are known and most pests are found boring in the seeds of leguminous plants and crops, both in the field and in storage. Many species are widely distributed as a result of being extensively transported with foodstuffs. In addition to Leguminosae many species are found in the fruits and seeds of Umbelliferae and Convolvulaceae.

Family **Chrysomelidae**
(Leaf Beetles) A large family with more than 26 000 spp. and many are important crop pests. Great diversity of form and habits, and the family is divided into distinct subfamilies.

Subfamily **Cassidinae**
(Tortoise Beetles) Adults are small beetles with an expanded dorsal skeleton, often brightly coloured; larvae are softly spiny and carry old exuviae posteriorly. Both adults and larvae eat holes in leaves; many species attack sweet potato.

Subfamily **Chrysomelinae**
(Leaf Beetles) Most of the species belong to this group; both adults and larvae are leaf-eaters; convex in shape; the notorious Colorado Beetle belongs here.

Subfamily **Criocerinae**
Adults rather elongate, but larvae short and stubby, sometimes covered with their own excreta. *Oulema* and *Crioceris* are important pests.

Subfamily **Eumolpinae**
Small, rounded beetles; the adults eat holes in leaves, and the larvae generally live in the soil. *Colaspis* spp. larvae are pests of rice and other crops in S. USA.

Subfamily **Galerucinae**
Also beetles convex in shape, adults and larvae usually together eating leaves. Generally considerable diversity of forms and habits within the group. Many are pests of crops and growing plants.

Subfamily **Halticinae**
(Flea Beetles) Adults are tiny, with swollen hind femora, and jump readily. Many are serious crop pests. Larval habits vary considerably; some live in the soil, some with the adults on the leaves, some are leaf-miners and some make galls in plant stems.

Subfamily **Hispinae**
Adults are small and spiny; tropical in distribution; adults scrape the leaf lamina; larvae mine inside the leaves, mostly on Gramineae, and Palmae.

Family **Apionidae**
(Weevils) Adults have clubbed antennae, normally not geniculate (elbowed). Larvae are typically weevils (i.e. Curculionoidea) being legless but with large mandibles; larvae live in the soil or roots, or in tubers; 1000 spp.; *Apion* larvae develop in seeds, stems or roots. *Cylas* is the Sweet Potato Weevil.

Family **Brenthidae**
(Weevils) Antennae of adults neither geniculate not clavate (clubbed); often narrow and elongate in body; in tropical forests.

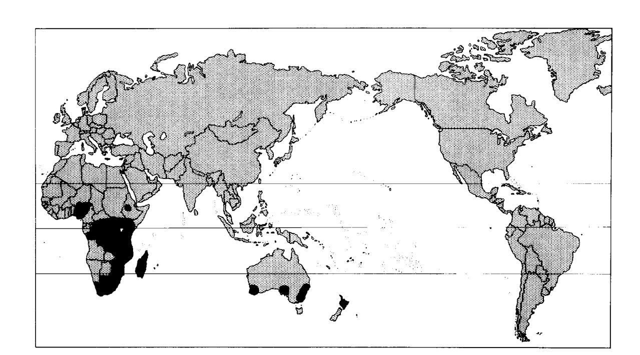
Family **Curculionidae**
(Weevils proper) A very large group, of more than 60 000 spp.; the adults have antennae geniculate and clavate. The snout may be elongate (rostrum) and narrow, or else short and broad; sometimes referred to as a 'nose' but the mouth is terminal. The elongate rostrum in many species functions as a boring instrument for egg-placing into the host plant tissues. The larvae show great similarity of form, but diversity of habits; some bore timber, some live in plant galls (all parts of the plant body are attacked), most live in the soil where the larvae eat roots. Some species lack wings; some lack males.

Family **Scolytidae**
(Bark and Ambrosia Beetles) Sometimes regarded as a subfamily of weevils, but are treated here as a separate family. The adults bore tunnels under the bark of trees and construct extensive breeding galleries. The Ambrosia Beetles are species which carry symbiotic fungi and cultivate the fungus in the breeding gallery for the larvae to eat. The larvae do not eat the wood of the host. Mostly pests of timber, but some species bore in thin branches and twigs and are pests of tea, coffee and other small trees and bushes. Many species are really secondary pests, but some are clearly primary pests.

Heteronychus spp.

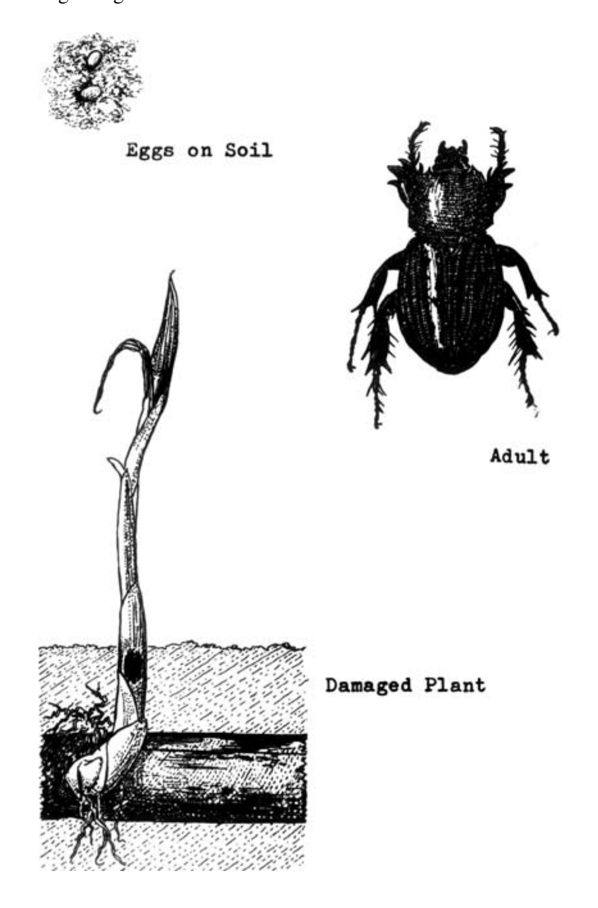
arator (F.)
consimilis Kolbe
licas (Klug)

Common name. Black Maize Beetle (Sugarcane Beetle) Black Wheat Beetle
Family. Scarabaeidae (Dynastinae)
Hosts (main). Maize, and wheat.
(alternative). Sugarcane, other cereals, yam, tobacco, vegetables and various wild plants.
Damage. The main damage is that done by the adult beetles to the young shoots just below ground level, the stems being eaten through. One adult beetle may destroy several seedlings in a row. Losses of young plants can be extensive. Some adult damage consists only of a hole in the side of the stem, with the resulting 'dead-heart'. The larval damage is less significant and consists of the roots being eaten away; the symptoms of larval attack are general wilting and yellowing of the leaves.
Pest status. These beetles are important pests of cereals and sugarcane in many parts of Africa, and *H. licas* is of some importance as a pest of yam.



Life history. Eggs are laid in moist soil at the base of the plants.
The larvae are soft bodied and fleshy, curved in a C-shape, with well-developed thoracic legs, like typical chafer grubs. The mature larvae are about 35 mm long. They feed below ground on the roots of the host plants, and they often destroy sugarcane stools and maize seedlings.
The adult is a black, rounded scarab beetle between 15 and 20 mm long.
There is usually only one generation per year.
Distribution. *H. arator* occurs in southern Africa, Madagascar, Australia and New Zealand (CIE map no. A163).
H. licas is found throughout tropical Africa, in Nigeria, Zaïre, Swaziland, E. Africa, Zimbabwe and S. Africa.
H. consimilis is apparently confined to E. Africa.
Control. The usual insecticidal treatment recommended were the use of seed dressings of aldrin or dieldrin. DDT, γ-BHC and chlordane were also recommended. Diazinon sprays can be applied to the soil before planting, and also the spraying of young sugarcane stools is recommended when one or more adult beetles are found in 20 damaged stools.

Fig. 9.151. Heteronychus sp. (Black Maize/Sugarcane Beetle), and damaged sugarcane stool.



Oryctes boas (F.)

Common name. African Rhinoceros Beetle
Family. Scarabaeidae (Dynastinae)
Hosts (main). Coconut palm
(alternative). Oil palm, date palm, and other Palmae.
Damage. The adult beetles feed on the growing point of the palm, eventually producing **V**-shaped cuts through the leaflets of mature palm leaves. Severely attacked palms will die and remain standing but leafless.
Pest status. A major pest of palms in tropical Africa. It may occur in areas where palms are not found in any number, such as Uganda.
Life history. Eggs are laid in rotting vegetation, especially in the trunks of rotting palms; they are white and oval, and about 3.5 mm long when freshly laid, later expanding to about 4 mm. Hatching takes place after 10–12 days. Each female lays about 40–50 eggs.

The full-grown larva is a soft, white, wrinkled grub some 6 cm or more in length, usually found curled up in its characteristic C-shaped position in the moist rotten vegetable matter on which it feeds. There are three larval instars; the total larval period lasts for two months.

The fat, brown pupa, about 4 cm long, is found in the rotting plant matter with the larvae; the pupal period is about three weeks.

The adult is a large, black, shiny beetle about 4 cm in length. It has the rhinoceros-type frontal horn which is well developed in the male, but short in the female. Adults rest during the day but fly strongly at night, and feed upon the 'cabbage' of the palm (the large terminal bud). With slight damage the leaves later unfold to show the characteristic V-shaped cuts, but if the actual growing point is eaten then the palm dies. The female beetle may live for 3–4 months and lay more than 50 eggs.
Distribution. This species is confined to tropical Africa and Madagascar (CIE map no. A298).
Control. See *Oryctes rhinoceros*.

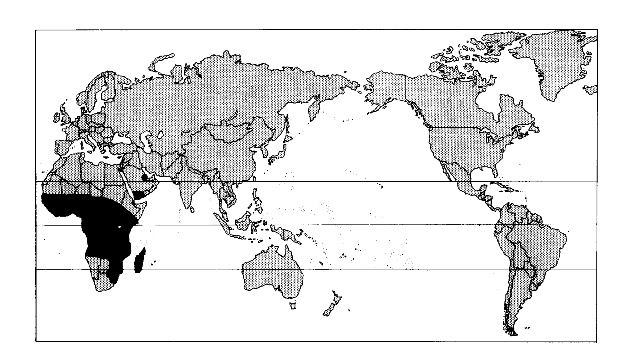
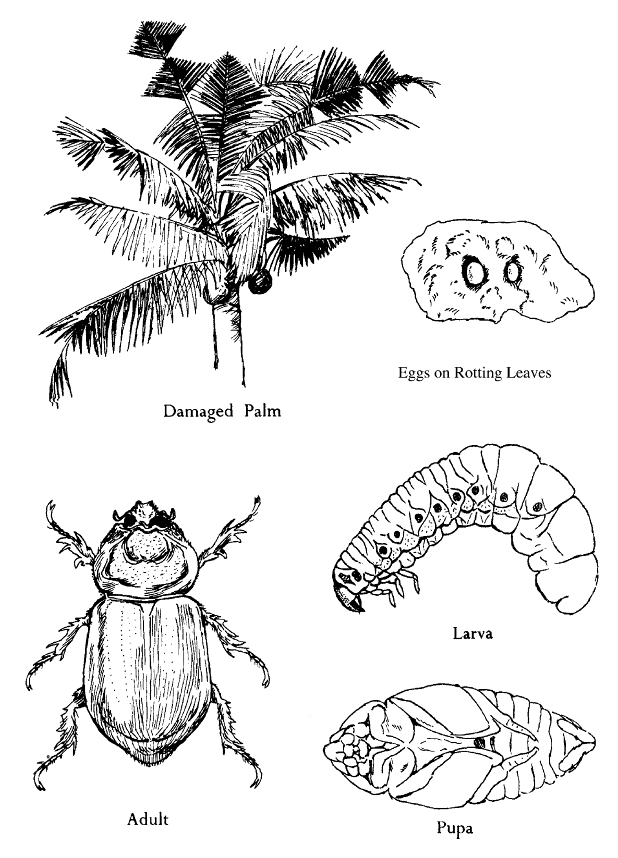


Fig. 9.152. Oryctes boas (African Rhinoceros Beetle): Kenya.



Oryctes monoceros (Oliver)

Common name. African Rhinoceros Beetle
Family. Scarabaeidae (Dynastinae)
Hosts (main). Coconut palm
(alternative). Oil palm, date palm, and other Palmae. For the adults only.
Damage. The feeding adults attack the growing point of the palm, and the eaten leaves eventually expand and produce the characteristic V-shaped cuts, as illustrated. The larvae and pupae are to be found in rotting vegetable matter and in soil.
Pest status. A major pest of palms in tropical Africa and its associated islands.
Life history. The life history details are similar to those of *O. boas*, on the previous page.
Distribution. *O. monoceros* is also found in tropical Africa, including Madagascar, Mauritius and the Seychelles (CIE map no. A188).
Control. See *Oryctes rhinoceros*.

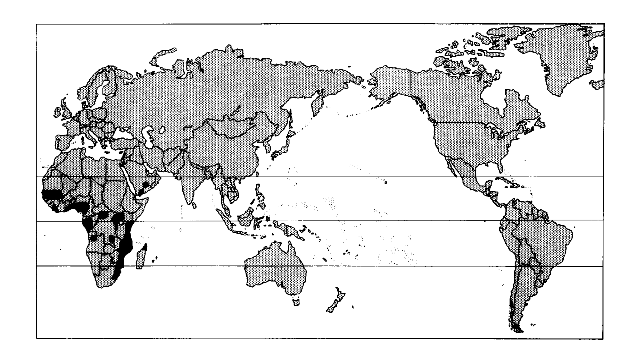


Fig. 9.153. Oryctes monoceros (African Rhinoceros Beetle): Seychelles (Also *O. rhinoceros).*





Damage



Larva

0 1cm

Oryctes monoceros



Coconut Palms showing foliage damage by feeding Rhinoceros Beetle adults (*Oryctes rhinoceros*; Col.: Scarabaeidae); the larvae live in compost in the soil.

Oryctes rhinoceros (L.)

Common name. Asiatic Rhinoceros Beetle
Family. Scarabaeidae (Dynastinae)
Hosts (main). Coconut, oil and date palms.

(alternative). Wild species of Palmae, sugarcane, banana, sisal, pineapple, papaya, and other plants.

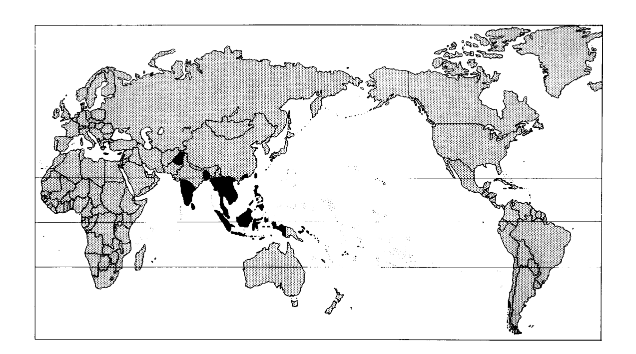
Damage. The adult beetles feed on the growing point of the palm, and their feeding on the young leaves eventually produces the typical V-shaped cuts seen on mature leaves (page 000). Heavy attacks regularly cause a serious reduction in crop yield. Damaged palms often become secondarily infected by fungal rots.

Pest status. A serious pest of cultivated palms throughout S.E. Asia and the Pacific region. Heavy yield losses have been reported.

Life history. The white, oval eggs are laid in rotting plant material, especially dead palm trunks, compost heaps and rubbish dumps. Hatching takes 10–12 days usually. The larvae grow to a size of 6–8 cm in length, after 2–4 months, according to temperature.

Within the pupal chamber in the soil or rotting plant material the mature larva turns first into a prepupa, before becoming a pupa proper; pupation takes, in total, 3–4 weeks, but the adult beetle may not emerge from the cocoon immediately, and the maturation period may be spent within the pupal cocoon in the soil.

The adult beetle is large and stout, ranging in size from 3–5 cm long; shiny and black above but a reddish brown ventrally. Adult longevity may be six months, during which each female may lay 90–100 eggs. In the field indistinguishable from *O.monoceros.*



Under optimum conditions one generation may only take 4–5 months; there is usually either one or two generations per year, according to locality.

Distribution. This is the common Asiatic species, being recorded from Pakistan and India, through S.E. Asia to Hainan and Taiwan, Philippines, Indonesia, Fiji, Samoa, etc. (CIE map no. A54).

According to Schmütterer (in Kranz, Schmütterer & Koch, 1979) there are altogether 42 species of *Oryctes* known, most of which attack palms, and many of which are similar in appearance.

Control. A single beetle is capable of flying long distances and attacking many different palms during its long adult life; it is essential therefore to organize an integrated programme simultaneously over a large area.

The recommended methods of cultural control are as follows.

(a) Plant all palms at the same time in close regular spacing so that a continuous canopy of foliage develops. Isolated palms, and palms of irregular heights, are particularly liable to be attacked.
(b) All dead palms should be cut down to short stumps and burned.
(c) All rubbish and rotting vegetation should be dried and burned.

Chemical control can be effected with sprays of BHC, DDT, dieldrin, diazinon, or carbaryl.

Prionoryctes caniculus Arr.

Common name. Yam Beetle
Family. Scarabaeidae (Dynastinae)
Hosts (main). Yam tubers. (adults)
(alternative). Roots of other plants such as bananas, coffee, grasses etc. in marshy areas. (larvae)
Damage. Holes are bored in the tubers by both larvae and adults but mostly by the feeding adults, the feeding lesions generally being hemispherical and 1–2 cm in diameter. The adults do the damage on their 'feeding migration' from the swampy areas in the forests.
Pest status. This and the other dynastine beetles are important pests of yam in W. Africa, particularly in Nigeria. Yield losses can be high and marketability of tubers reduced.
Life history. Eggs are laid in moist soil early in the dry season. The polyphagous young larvae initially feed on organic debris, and later feed on roots. At this stage the larvae are usually in swampy areas where yams are not often available.

After pupation in these areas the adults emerge early in the rainy season; usually a storm bringing at least 1–5 cm of rain is required to stimulate emergence of most of the adults. After emergence the adults make their migratory flight to the feeding areas where the yams grow. At this stage the beetles are sexually immature, and this migration is referred to as the 'feeding migration'. On the arrival in the yam fields, the beetles burrow in the soil around the base of the yam plants and here they feed on the tubers, making holes and tunnels. At the end of the rainy season the adults fly back to the breeding grounds in the swamps or river flood plains.

There are three larval instars, a quiescent prepupal stage, and the pupal stage. The larvae are white or grey, with a pale brown head capsule. The relative lengths of the different developmental stages are as follows: 18–21 days; 17–23 days; 65–78 days; prepupal stage 6–9 days; and pupal stage 17–20 days.

The total developmental period is recorded from 138–171 days in the laboratory.
Distribution. Tropical Africa only. But a similar group of beetles are found in the Pacific.
Control. The use of organochlorine contact insecticides applied to the yam setts or the soil has been very successful. The recommended insecticides were aldrin, dieldrin, chlordane, γ-BHC. The best results have been obtained by dusting the planting setts with aldrin and γ-BHC.

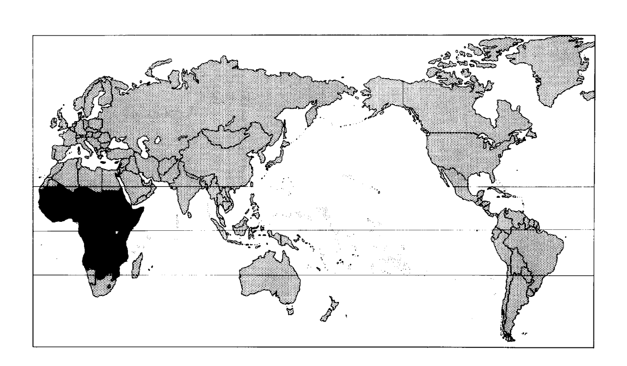


Fig. 9.154. Prionoryctes caniculus (Yam Beetle).











Cochliotis melolonthoides (Gerst.)

Common name. Sugarcane Whitegrub
Family. Scarabaeidae (Melolonthinae)
Hosts (main). Sugarcane roots.
(alternative). Roots of many other plants and many trees.
Damage. The attacked crop appears as if affected by drought, with the yellowing of leaves and drooping of the spindle. Later the leaves may die, and in severe cases the stool is deprived of its roots and will fall because of its own weight. Occasionally the base of the stool may be eaten.
Pest status. This has been a serious pest in Tanzania where it has reduced potential yields of 110–195 tonnes of plant per hectare to less than 24 tonnes. 49 000 or more grubs per hectare cause serious damage; 19 000–49 000 cause patches of yellowed cane in the crop.
Life history. The eggs are subspherical, whitish, and deposited in the soil at depths to ensure moisture for development. They hatch after 10–25 days.

Three larval instars occur; during development the head capsule increases in size only at ecdysis but the soft flexible body does increase all the time. The larvae (grubs or whitegrubs) are difficult to distinguish from other Scarabaeidae. The first instar lasts about 30 days, the second a little more, and the third instar lasts much longer and may be six months or more. The third-stage larva feeds voraciously for 3–4 months and then burrows deeper into the soil (0.5–1.0 m) and becomes inactive.

After a while pupation takes place, in an earthen cell, and it takes about 30 days. The young adult remains in the cell while the cuticle hardens.

In Tanzania, eggs and young are abundant from December onwards, third-stage larvae are most abundant in the period June–August, after which they pupate. Adults emerge in October and November. The life-cycle takes about one year to complete. Adults emerge in the evening, after rain, and during the day they hide in the soil. They are large, fat, brown beetles of typical scarab appearance, 25–28 mm long, with a faint pale speckling of white scales over the body.
Distribution. Only recorded to date from Tanzania.

It is, however, a typical chafer grub or white grub, and is representative of the family which is of considerable importance in all parts of the world on a wide range of crops. For example, Box (1953) listed 80 species of Melolonthinae, 40 of Rutelinae and 65 of Dynastinae (all Scarabeidae) associated with sugarcane. As reported by F. Wilson (1971), in the grasslands of Australia there are times when there is a total weight of chafer grubs in the soil greater than that of the sheep grazing on the surface.
Control. See following section on the control of chater grubs.

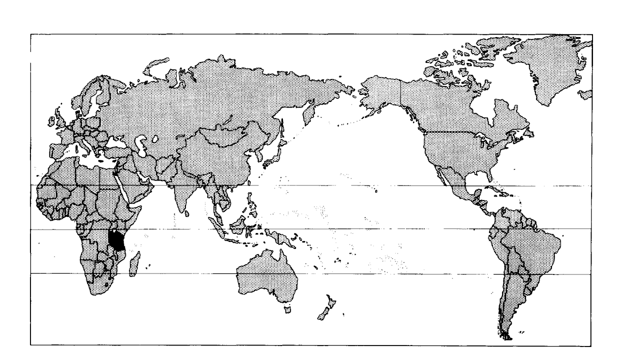
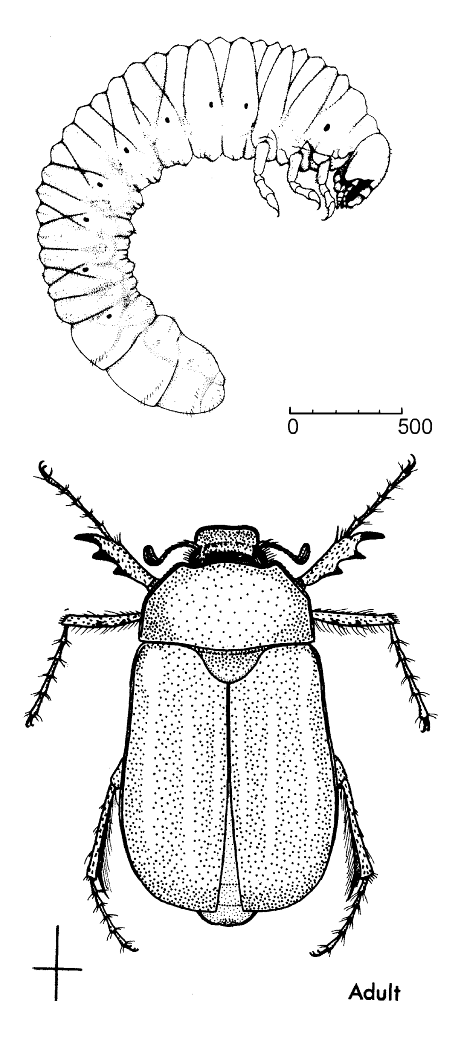


Fig. 9.155. Cochliotis melolonthoides (Sugarcane Whitegrub); Tanzania.



Chafers and chafer (white) grubs

(Coleoptera: Scarabaeidae)

This large family, with more than 19 000 species, falls into several distinct groups, here regarded as subfamilies but sometimes given status as separate families. The adults are rather similar in appearance, but the larvae which are the major pests are almost indistinguishable from each other, though easily recognized as a group; they are fleshy grubs with a swollen abdomen, usually adopting a C-shaped position, with a well-developed head capsule and large jaws, and thoracic legs. This typical larval shape is known as 'scarabaeiform'. Some larvae live in rotting wood or rotting vegetation or animal dung, but the majority live in soil and eat plant roots and these pest species are referred to as 'white grubs' or 'chafer grubs'. The feeding larvae generally live at depths of 2–10 cm in the soil, but hibernation may take place as deep as 110 cm in Canada where the winter is very cold. Pasture populations of larvae are regularly more than 30 per square metre, and up to 900 per square metre are recorded in Canada. Some species are restricted in their diet to roots of Gramineae, but many are polyphagous; many crops are damaged as well as pastures and grass leys; damage to qualify turf such as golf courses, playing fields and lawns may be very costly. In the tropics most damage is done to sugarcane and cereal crops; in temperate regions quality turf and root crops may be the most severely damaged, although many crops are attacked. Damage to root crops consists of holes eaten into the tuber or root (see page 78), usually rather wide and shallow holes. Crops most at risk from chafer grubs are those which are grown in newly ploughed grassland, and both wireworms and leatherjackets are to be expected also.

Subfamily Cetoninae (Rose Chafers)

Largely a tropical group (2600 species); these beetles have a brightly coloured, flattened body, and the elytra are characteristically emarginated laterally. In flight the elytra are only raised slightly and the wings project through these emarginations. The beetles are usually diurnal in habit and fly to flowers (usually on trees and shrubs) to feed on nectar and pollen with their weak mouthparts. They will also feed on soft over-ripe fruits, but because their very weak mouthparts are almost nonfunctional the adults are not pests themselves.

Pest species are found in the subtropical Asiatic genus *Protaetia* and the temperate *Cetonia*.

Subfamily Coprinae (= Scarabaeinae) (Dung Beetles)

These black rounded beetles are not crop pests, although common on pastures, and neither are their coprophilous larvae.

Subfamily Dynastinae (Rhinoceros and Elephant Beetles)

These are tropical rain forest beetles, many large in size, all black in colour, and nocturnal in habits. The larvae generally live in rotting vegetation where they feed saprophagously, and the adults do damage by eating the foliage of trees and palms, though a few attack Gramineae. The main pests are the many species of *Oryctes* (rhinoceros beetles) that damage the crowns of palms (Palmae), and the giant *Xylotrupes* feeds on the foliage of some tropical trees. *Heteronychus* includes the cereal beetles of Africa and Australia that are also pests of sugarcane.

Subfamily Melolonthinae (Cockchafers)

Usually dull brown beetles with fat rounded bodies; elytra held vertically in flight; nocturnal, and fly to lights at night; claws of hind legs equal in size and immovable. The larvae are serious crop pests in the soil. The adults have strong biting mouthparts and eat leaves of trees and shrubs and bite pieces out of young fruits such as apples.

Some important tropical pest species are in the genera:
Dermolepida – (Sugarcane Beetles; Greybacks) Australia.
Lepidiota – (Sugarcane Whitegrubs) tropical Asia and Australasia.
Leucopholis – (Chafer (White) Grubs) Philippines.
Schizonycha – (Chafer Grubs) polyphagous; throughout Africa.

Some of the more important temperate pest species are in the genera *Amphimallon* and *Melolontha*, as well as the following:
Holotrichia – (Chafer Grubs) China and parts of Asia.
Hoplia philanthus – (Fuessly) – (Welsh Chafer) Wales and western England.
Phyllophaga anxia Le. – (Common June Beetle) polyphagous; Canada.
Phyllophaga fusca (Froel.) – (Northern June Beetle) Canada.
Phyllophaga spp.–(June Beetles, etc.) atleast 20 species are pests throughout Canada, USA, C. and S. America; adults eat leaves of trees and field crops, and larvae polyphagous.
Serica brunnea (L.) – (Brown Chafer) polyphagous, but basically a woodland species, not grassland; UK and northern Europe.
Serica orientalis Mots. – (Oriental Brown Chafer); China.
Serica spp. – (Brown Chafers) polyphagous; India and parts of Asia.

Subfamily Rutelinae (Flower Beetles; June (May) Beetles)

The common English name refers to the time of flying adults (to lights), and so there is variation in different

parts of the world: in Australia the several important species of *Anoplognathus* are referred to as Christmas beetles. The body is smooth, oval and shiny; occasionally bright metallic; the hind legs have thickened tibiae and long movable claws of unequal length. Adults are mostly nocturnal and will fly to lights at night; they have well-developed mandibles and feed on foliage of trees and shrubs as well as ornamental herbaceous plants, eating both leaves and flowers. The genus *Popillia* is active during daylight hours: beetles can be found both feeding and flying by day.

Common pests include *Phyllopertha* and *Popillia*, as well as the following:

Adoretus spp. – (Flower Beetles) adults and larvae polyphagous; pantropical in the Old World and now established in the USA.

Anomala spp. – (Chafers, etc.) polyphagous; found throughout Africa, Asia (both tropical and temperate), and in the USA (16 pest species recorded in Japan).

Anoplognathus spp. – (Christmas Beetles) polyphagous; Australia.

Lachnosterna spp. – (White Grubs) polyphagous root pests; Canada, USA, West Indies.

Control of chafers and chafer grubs

Adults are generally difficult to control because of their mobility and nocturnal activity, but *Popillia* adults feed in daylight and can be sprayed whilst on the foliage of the plants. Some population control of adults has been achieved in places using ultra-violet light traps at night.

Larvae are the main pests, so most control measures are directed against them. Several different approaches have been used in the past, with some success, and these aspects need to be borne in mind in any future IPM programme.

(1) Natural control – predators of some importance include wasps in the families Scoliidae and Tiphidae (Digger Wasps), some beetles (Carabidae, Histeridae), many different species of birds, moles and other Insectivora, and in North America skunks may be serious predators. Deliberate introduction of predatory insects to control chafer grubs has met with mixed success. Parasites include several species of Tachinidae, several nematodes, a bacterial disease called ‘milky’ disease, and the fungus *Cordyceps*.

(2) Cultural control – deep ploughing will expose larvae and pupae to both predators (such as bird flocks following a plough) and adverse weather conditions. Crop rotation may be used to avoid the more susceptible crops while there are large numbers of larvae still in the ground. The avoidance of planting susceptible crops in newly ploughed grassland. Rototilling the soil will physically kill some of the larvae and pupae.

In some areas light trapping (u.v.) for adults has proved successful in long-term population control.

(3) Chemical control – to date the only really successful insecticides for killing chafer grubs has been the organochlorines, aldrin, DDT, dieldrin, HCH (BHC), heptachlor and chlordane, but resistance to these chemicals has long been established in both USA and some parts of Europe.

In the USA the organophosphorous compound isofenfos has given good results at 2.2 g a.i./ha for control of chafer grubs on golf course turf, and it was expected to be registered for use on corn and turf-grass in the USA in 1981/82.

Other insecticides regularly used include diazinon, carbaryl and isofenphos.

Schizonycha spp.

Common name. Chafer Grubs
Family. Scarabaeidae (Melolonthinae)
Hosts. Wheat, maize, sugarcane, sorghum, groundnut, sunflower, yam, and many other crops and weeds.
Damage. The larvae are soil dwellers and damage the roots of many crop plants, and the pods of groundnut. Freshly turned soil, especially with a high organic content, is reputed to be attractive to the adult beetles. The adults do a certain amount of foliage damage but this is generally not important.
Pest status. A fairly important pest found on many crops in Africa. As a group the polyphagous chafer grubs are found throughout the world and the total damage to crops by this group must be tremendous.
Life history. Eggs are laid in the soil, especially where there is a high organic content.

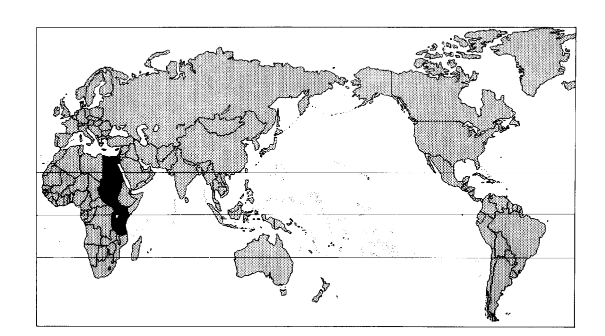
The larvae are white, fleshy, with a curved C-shaped body and swollen abdomen, and well-developed thoracic legs. The larval stage lasts for about six months.

Pupation takes place in an earthen cell in the soil, and lasts for about 14 days.

The adult is a shiny brown cockchafer, about 15 mm long, and nocturnal in habits.

The life-cycle takes about seven months, and there is only one generation per year.
Distribution: Africa only; E. Africa, Sudan, Egypt.
Control. Deep ploughing will kill a number of larvae and pupae both directly and by exposure to sunlight and predators. Large numbers of adults can be caught in light traps.

Seed dressings or soil treatments with aldrin, dieldrin, heptachlor, or γ-BHC were generally effective; for recent recommendations see page 276.



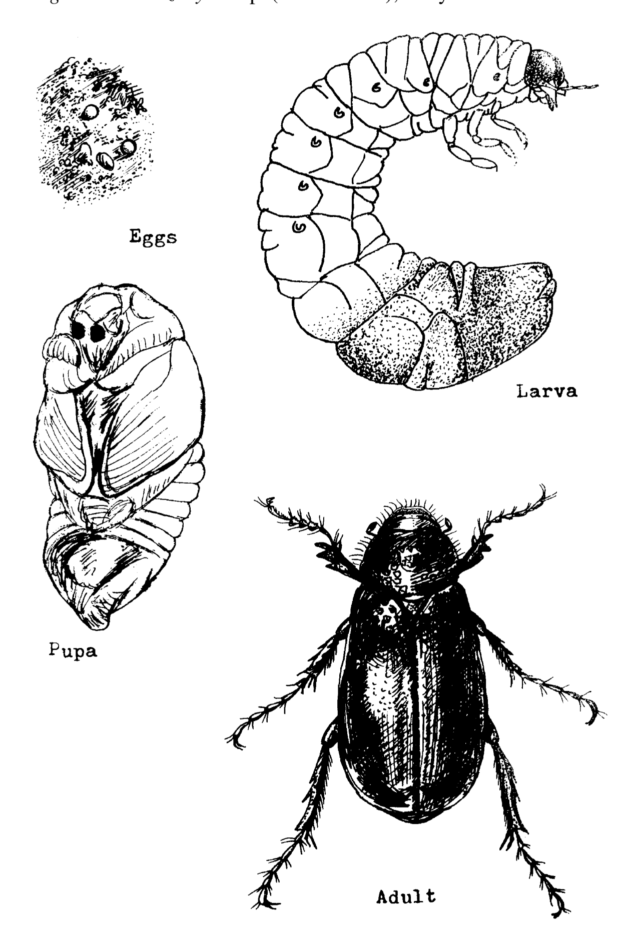


Fig. 9.156. Schizonycha sp. (Chafer Grub); Kenya.

Anomala cupripes (Hope)

Common name. Green Flower Beetle
Family. Scarabaeidae (Rutelinae)
Hosts and Damage. The genera *Anomala, Adoretus* and *Popillia* are collectively known as Flower Beetles (subfamily Rutelinae), and the adults damage the foliage (leaves and inflorescences) and sometimes fruits, of a wide range of crop plants and ornamentals throughout most parts of the world, but more abundantly in warmer climates. The larvae are typical Chafer Grubs or White Grubs, along with the other members of the Scaraboidea, and they live in the soil (or dead trees) and eat the roots of many different plants. As a group they are probably most damaging to pastures.
Pest status. Individually any one species is probably not particularly important (except for *Popillia japonica* in N. America), but, collectively they are quite abundant in most parts of the world, and commonly encountered on crops and ornamentals, and in soils, where the different species do much the same sort of damage.
Life history. Eggs are laid in the soil, and the developing larvae live underground for many weeks or months, where they feed on fine roots, eating them with their biting and chewing mouthparts. Larval development in soil is generally rather slow, and these larvae probably require several weeks or months for their development, according to their geographical location. The larvae are referred to as 'scarabaeiform', being oligopodous and eucephalous, with well-developed thoracic legs and head capsule bearing strong mandibles, but the distal end of the body is generally swollen and the whole body is held in a C-shaped position, when not crawling. Mature larvae measure some 20–60 mm in length, according to species; *A. cupripes* is about 35 mm long.

Pupation takes place in the soil in an earthen cocoon; in cooler climates the pupa overwinters in a state of diapause. There are usually one or two generations per year.

The adult is a smooth, shiny beetle, a green colour dorsally and bright coppery underneath, and about 25 mm in body length. The tibia on the hind legs are rather thickened, and there are long movable claws of unequal size on the tarsi. The adults are nocturnal and fly to lights at night. They can be found on vegetation during the day, but most activity is at night when they eat the leaves and flowers, and sometimes the fruits, of the host plants.
Distribution. This species of *Anomala* is confined to S.E. Asia (mainland) but other species occur in India and tropical Africa, and China. The group of similar genera belonging to the Rutelinae are cosmopolitan throughout the warmer parts of the world.
Control. When control of the soil-inhabiting larvae has been required in the past, dieldrin and chlordane gave good results, but in some parts of the world the chafer grubs are now totally resistant to most organochlorines; isofenphos is giving promising results in the USA. See page 276.

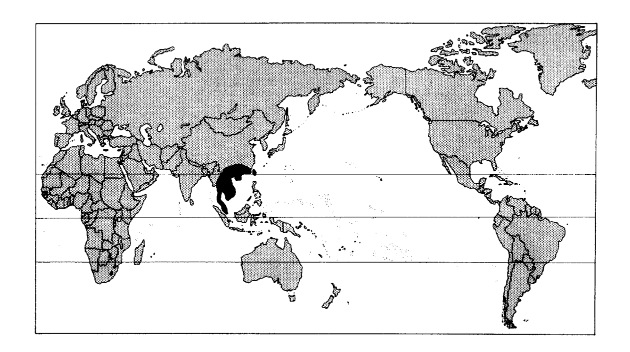
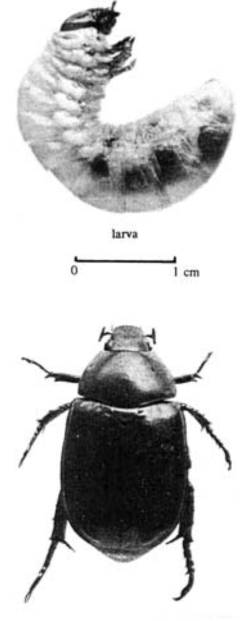


Fig. 9.157. Anomala cupripes (Green Flower Beetle); Malaya.



Agrilus spp.
A. auriventris
A. occipitalis

Common name. Citrus Jewel Beetles; Citrus Bark Borers, etc.
Family. Buprestidae
Hosts (main). *Citrus* spp.; others on fruit trees, etc.
(alternative). Other members of the Rutaceae, and a wide range of deciduous trees.
Damage. The larvae bore flat winding galleries just beneath the trunk of the tree; often sap exudes from the cracked bark, but there are usually no frass holes; heavy infestations generally kill the tree by ring-barking.
Pest status. An important pest of *Citrus* in the Philippines (*A. occipitalis*) where damage is sometimes serious; somewhat less important in China (*A. auriventris*). The genus is however widespread and is a pest of several ornamental trees in the USA and Europe, as well as chestnut, pear and rose, and individuals are sometimes found in domestic situations when adults emerge from wood used in furniture.
Life history. Eggs are laid in cracks in the tree bark, and the young larvae bore into the bark, where eventually they make long winding galleries (tunnels) that are flat in section. Larvae measure from 15–25 mm according to species, and are legless, with a reduced head and laterally expanded prothorax, which gives them their common name of Flat-Headed Borers (F. Buprestidae).

Pupation takes place within the gallery, just under the surface of the bark. Buprestid larvae generally do not make frass holes as they burrow (as do Cerambycidae) but they pack the frass tightly in the gallery behind them as they tunnel.

The adults are small, greenish or bronze beetles, 15–20 mm in length; they may live for several weeks and feed on the tree foliage.
Distribution. *Agrilus occipitalis* is recorded from the Philippines and Java; *A. auriventris* on *Citrus* in China and Japan. *A. acutus* is the Jute Stem Buprestid of India, also on kenaf in Sumatra and roselle; and other species occur in S.E. Asia and Papua New Guinea. A couple of species occur in Europe, on oak and other forest trees, and six species in the USA on pear, poplar, birch, chestnut, raspberry and blackberry canes. On a worldwide basis, 700 spp. of *Agrilus* are known.
Control. When control has been required, the systemic insecticide dimethoate as a foliar spray has been effective. Good husbandry will reduce the likelihood of attack by this pest, as it has been noticed that trees under physiological (or water) stress are most heavily infested.

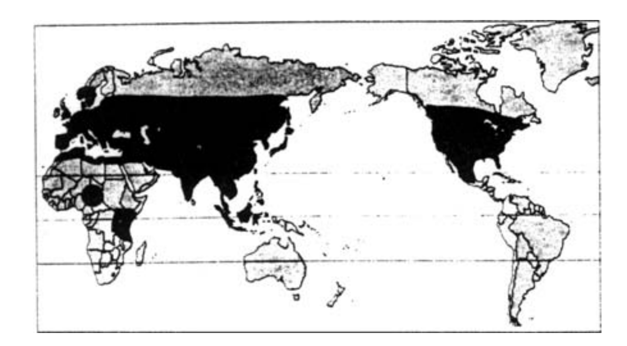
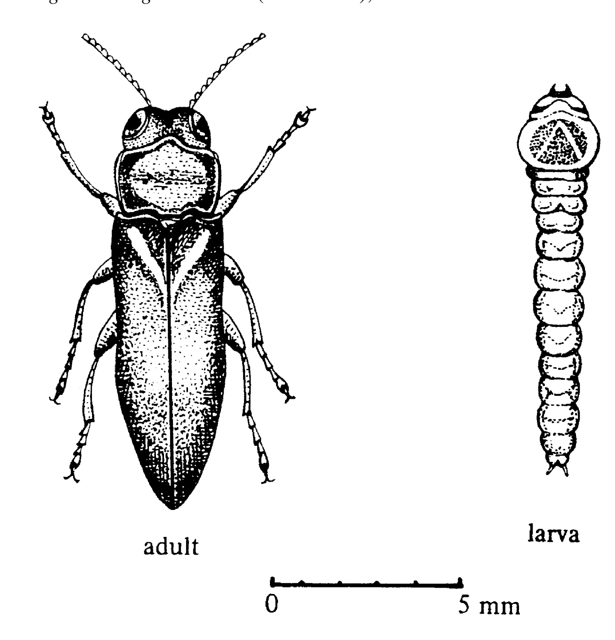


Fig. 9.158. Agrilus viridis (Bark Borer); S. China.



Trogoderma granarium Everts

Common name. Khapra Beetle
Family. Dermestidae
Hosts (main). Cereals and groundnut.
(alternative). Pulses, spices, and various cereal and pulse products (cakes).
Damage. The larvae bore in the stored cereal grains and pulses, usually hollowing out the grain. Development is rapid in the hot humid tropics and very large populations may build up quickly. The pest is fairly polyphagous and can survive in facultative diapause for a year or longer in the absence of food.
Pest status. Although virtually cosmopolitan, this pest is absent from E. Africa and S. Africa, and these countries have legislation to prevent its importation. A very serious pest of stored grains and pulses in most of the warmer parts of the world. It is the only member of the Dermestidae that is phytophagous.
Life history. Eggs are laid in the stored produce, and the larvae are regarded as primary pests of stored grains in that they can damage intact grains and seeds. Each female lays 35–40 eggs. The larvae often develop at different rates, some coming to maturity in two weeks and others taking months or even more than a year. In the absence of food the larvae can go into a state of facultative diapause for many months which ensures their survival at times when the store is empty; at these times the larvae congregate in large numbers in crevices and cracks in the buildings or storage containers, they can live for 9 months to 6 years. The critical temperature for development is 21°C.

The adults are small dark beetles 2–4 mm in body length; they are winged, but do not fly neither do they feed; they live for about 14 days. Thus, this species is spread almost entirely through the agency of man, and quarantine regulations against it may be easily enforced.

Under optimum conditions the life-cycle can be completed in about three weeks (37°C and 75% RH).
Distribution. Almost cosmopolitan in the warmer parts of the world, but as yet kept out of the countries of E. and S. Africa; it prefers a hot dry climate.

Now eradicated in some countries by regular fumigation and quarantine proceedures. Four other closely related species are known.
Control. A difficult pest to control in that many of the usual contact insecticides used against Coleoptera have little effect; the effect of its being able to practice facultative diapause results in infestations reappearing after a long storage period. Fumigation with toxic materials such as methyl bromide are most likely to give the best control results, but pirimiphos methyl is reputed to be effective.

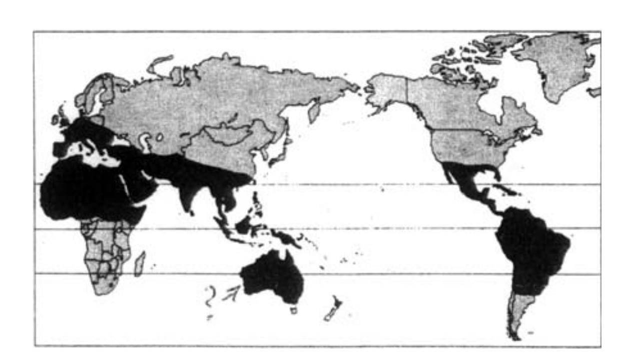
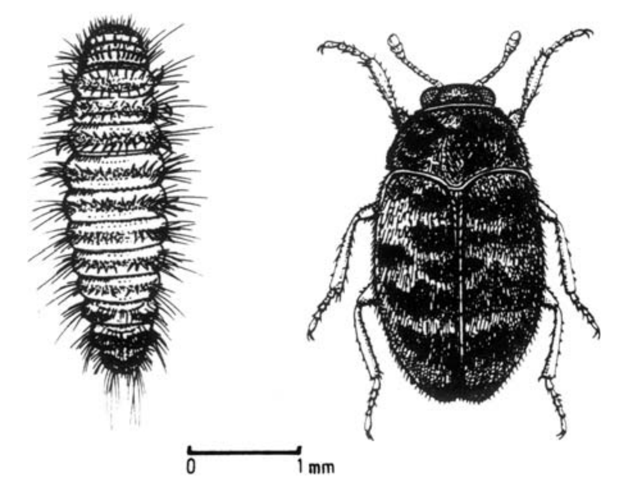


Fig. 9.159. Trogoderma granarium (Khapra Beetle).



Lasioderma serricorne (F.)

Common name. Cigarette Beetle (Tobacco Beetle)
Family. Anobiidae
Hosts (main). Tobacco (stored leaf and cigarettes).
(alternative). Cocoa beans, groundnut, peas and beans, many stored grains, flours and foodstuffs.
Damage. The larvae can attack undamaged cereal grains and pulse seeds, and often show preference for the germ of the seed for feeding. In packaged cigarettes holes are made in the packets by larvae and adults.
Pest status. This can be a very serious pest in many stores, owing to the wide range of foodstuffs attacked. High populations can build up very quickly and cause considerable damage. The adults fly readily at dusk, but most dispersal is effected by trade.
Life history. This beetle breeds anywhere at temperatures above 19°C and above a RH of 20–30%, but 30–35°C and 60–80% RH are optima.

Eggs are laid soon after the emergence of the females, and require 6–10 days to hatch (100/♀).

The newly hatched larvae are very active, negatively phototaxic, and capable of penetrating tiny holes in search of food. In closely packed produce such as meal, the infestation remains peripheral. Older larvae are scarabaeiform and less active. The fourth larval instar stops feeding and builds a cell on some firm foundation for pupation. Larval development on good foodstuffs takes 17–30 days.

Pupation takes 3–10 days, and the pre-emergence maturation period of the adult is also 3–10 days.

The adults are small brown beetles 3–4 mm long with the typical deflexed head of this family. The adults drink but do not feed, and cause most of their damage by making emergence holes when they bite their way out of their cocoons; they live for 2–6 weeks, and can fly freely.

The total developmental cycle takes about 26–50 days, according to climate and the quality of the food, tobacco being a poor food (at 50 days), can live for 120 days at 20°C.
Distribution. Cosmopolitan in the warmer parts of the world, but found only in heated stores in colder regions; distribution is essentially controlled by temperature and humidity (above 19°C and 30% RH).
Control. This pest can be killed by exposure to low temperatures; below 18°C development ceases; adults are killed after 6 days at 4°C.

Chemical control in foodstuffs can be effected by most fumigants, and also such contact and stomach poisons as γ-BHC, which also have some fumigant action.

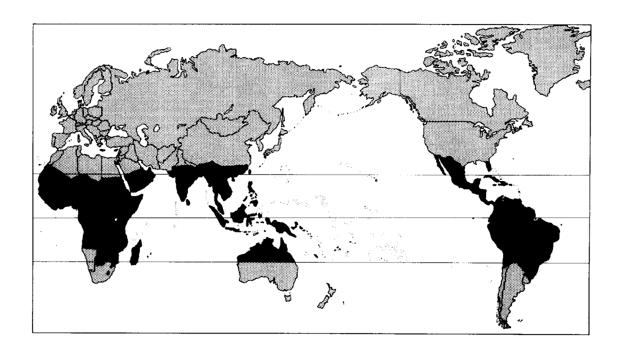
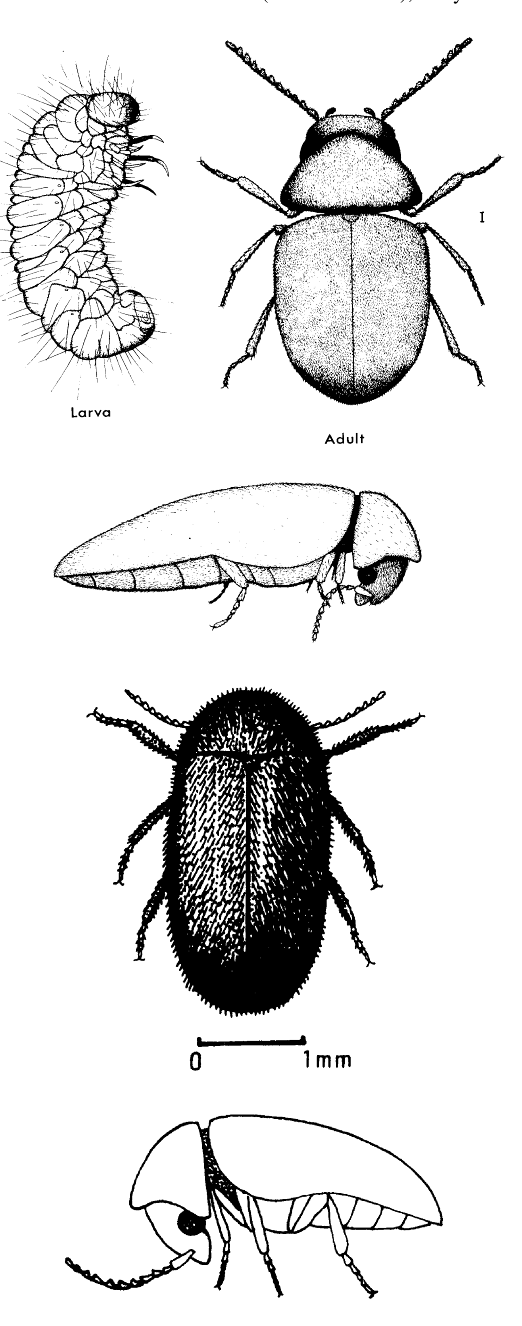


Fig. 9.160. Lasioderma serricorne (Tobacco Beetle); Kenya.



Melittomma insulare Fairm.

Common name. Coconut Palm Borer
Family. Lymexylidae
Hosts (main). Coconut palm
(alternative). Oil palm, and various wild Palmae.
Damage. The beetle larvae bore in the bole and trunk of the palm, causing general impairment of growth, and some palms break just over ground-level, at the rot-cavity.
Pest status. A serious pest with a very restricted distribution, confined virtually to the coconut palm as host.
Life history. Eggs are laid at the base of the trunk in clusters of up to 100 or more; each female probably lays about 250 eggs on average. Each egg is white, sausage-shaped and about 1.2 mm by 0.3 mm in size. The larvae are creamy white, rather thin and with a strange 'tail-piece', a hoof-shaped, heavily chitinized structure with the posterior face concave and studded with about 18 small pits. The tail-piece is used to ram the borings towards the mouth of the tunnel where they appear as small pellets resembling sawdust. Mature larvae are about 20 mm in length and 3 mm in body thickness. The larvae are also odd in that they apparently do not eat the woody material of the palm trunk (as do most timber borers) but they chew pieces to extract the sap and then push the chewed remains with their legs to the back of the tunnel. The duration of the larval stage is about one year, or more under unfavourable conditions.

Pupation takes place in the larval tunnel, after the larva turns round to face the exterior, and takes some 10–12 days.

The adult is a slender, dark brown beetle, 10–15 mm in body length, with large eyes and serrate antennae. Males are usually smaller than females. Males have a conspicuous branched appendage on the maxillary palps, which is characteristic of the family Lymexylidae. The adults are short-lived, and survive for only 2–6 days.

There is usually only one generation per year and there does not seem to be any seasonal life-cycle.
Distribution. Only recorded from Madagascar and the Seychelles (CIE map no. A152).

Melittoma sericeum (Harris) is the chestnut Timber-worm of the USA.

Another specis of *Melittoma* occurs in Australasia.
Control. Various cultural practices can reduce the level of infestation; for example, the cutting of steps in the trunk encourages infestation, the burning of fallen palms will kill the larvae and pupae inside the trunk, careful cultivation to promote good growth will reduce attack levels, etc.

For chemical control the most successful was to scrape out the damaged tissues and then to apply the fumigant paradichlorobenzene as crystals to the damaged trunk base and to earth-up the bole of the trunk.

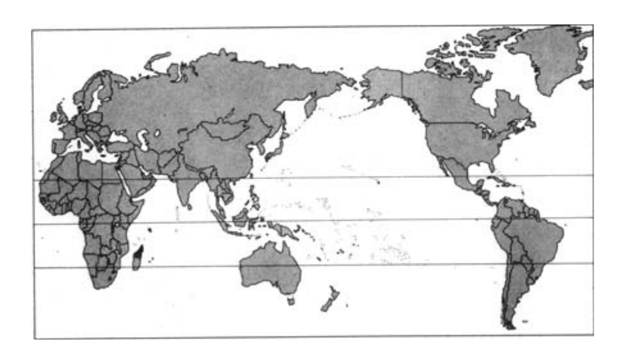
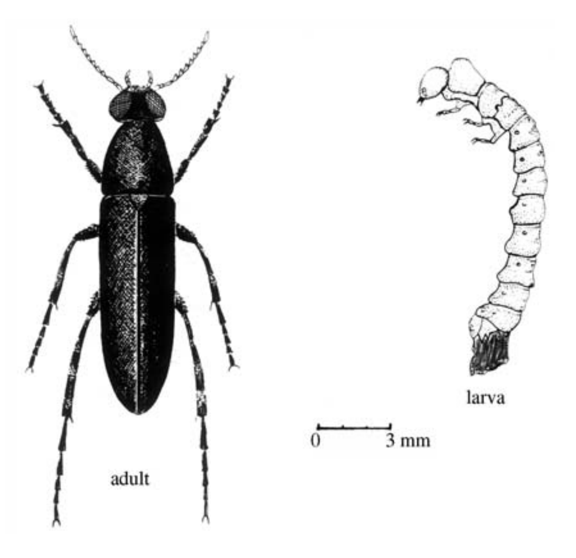


Fig. 9.161. Melittomma insulare (Coconut Palm Borer).





Carpophilus hemipterus (L.)

Common name. Dried Fruit Beetle
Family. Nitidulidae
Hosts (main). Primary pest on dried fruits, especially currants, raisins, dates and figs.

(alternative). In the field, these are found as secondary pests in cotton bolls, maize cobs, and on different types of fruit. In stores they also attack copra, cocoa beans, and groundnuts.

Damage. Both adults and larvae feed on the dried fruits, causing direct damage and also soiling the produce with their frass. Transmit fungi to damaged and ripe dates and can cause serious crop loss.

Pest status. A serious pest of dried fruits, and some other produce, in the warmer parts of the world; not serious as a crop pest, except on dates.

Life history. Life history details are not available, but it is known that eggs are laid amongst the dried fruits and that both larvae and adults feed on the fruits. The larvae are campodeiform in shape, white or yellow in colour, and bear two small pairs of horns at the end of the abdomen.

The adults are small, flat beetles, 3–4 mm in body length, have characteristic yellow patches on the elytra, and the terminal two body segments are left uncovered by the short elytra.

There are three other species to be found in food stores all over the world, the others being *C. dimidiatus* (F.), *C. obsoletus* (Erich), and *C. ligneus C. dimidiatus* (F.) is found in flowers of many crops (citrus, mango, peach, pear, plum, guava, grapevine, castos, etc.) : Africa, India Japan of the USA Murray; all four species are difficult to separate.

Distribution. Cosmopolitan, and extending up into northern parts of Europe and N. America.

Control. The usual recommendations for stored products pests are effective against this pest. The normal practice is for general warehouse fumigation, at intervals of time, which effectively controls all the pests that are likely to be present.

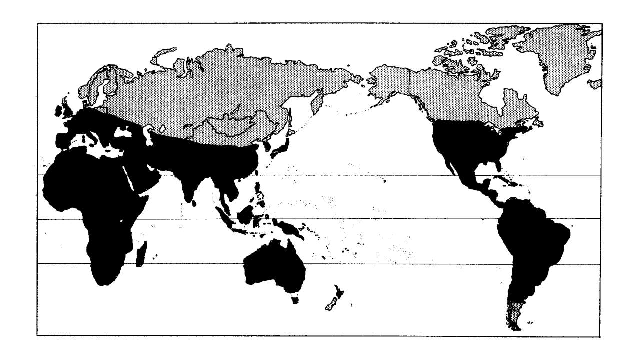
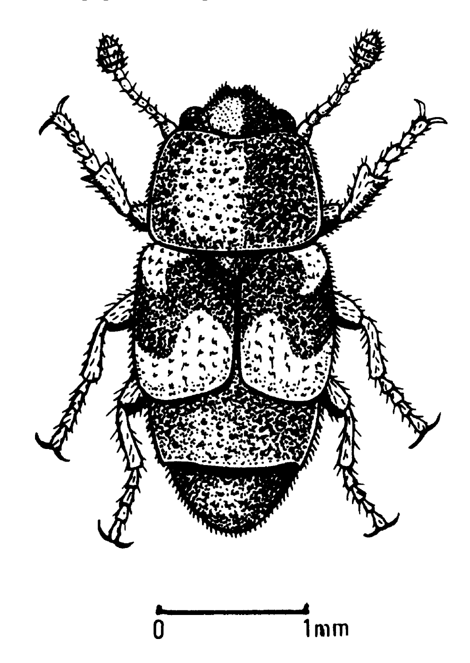


Fig. 9.162. Carpophilus hemipterus (Dried Fruit Beetle); Kenya.



Oryzaephilus *spp.*
surinamensis (L.)
mercator (*Fauvel)*

Common name. Saw-toothed Grain Beetle; Merchant Grain Beetle
Family. Silvanidae
Hosts (main). Stored grains.
(alternative). Other plant and animal stored products.
Damage. *Oryzaephilus* beetles are general feeders, and usually secondary on stored products, following the more destructive primary pests such as Grain Weevils and pyralid moths. Their actual diet consists of fragments of animal and plant debris.
O. surinamensis is more frequently found on cereal products, and *O. mercator* on oil-seed products.
Pest status. Not particularly important, since they are both secondary pests, but these two species are of very common occurrence and are widespread in distribution. Because of their small size they can easily hide in small crevices and are easily transported.
Life history. The entire life-cycle takes place in the stored produce. Egg mortality is high below 20°C; 30°C appears to be about optimum for development; egg development takes 4–12 days. The female lays 300–400 eggs.

The larvae are free-living however, and only spend part of their time within the grain, but when there they prefer to feed on the germ. Higher humidities are preferred (60–90% RH) for larval development, which takes about 12–20 days.

The pupal period is 5–15 days.

The adults are small, narrow, flattened beetles, red-brown, some 2.5–3.5 mm in length, with 11-segmented antennae, six large lateral 'teeth' on either side of the prothorax and three low longitudinal ridges. The preoviposition period is 3–6 days in the female.

O. surinamensis is distinguished from *O. mercator* by the shape of the head behind the eyes – the temple being drawn out into a rounded point in *mercator*, but flat and nearly equal to the vertical eye diameter in *surinamensis* – and in the male genitalia.
Distribution. Both species are virtually cosmopolitan in distribution in food stores and godowns, but *O. mercator* more tropical
Control. These species cannot breed at temperatures of less than 18°C, so in temperate countries infestations can easily be controlled by cooling the grain. *O. mercator* is the more temperature-sensitive.

For chemical control methyl bromide fumigation is particularly effective against the adult beetles. Aluminium phosphide, and a mixture of ethylene dichloride and carbon tetrachloride, are both commonly used on farms.

Insecticides recommended as sprays include malathion, fenitrothion, and γ-BHC.

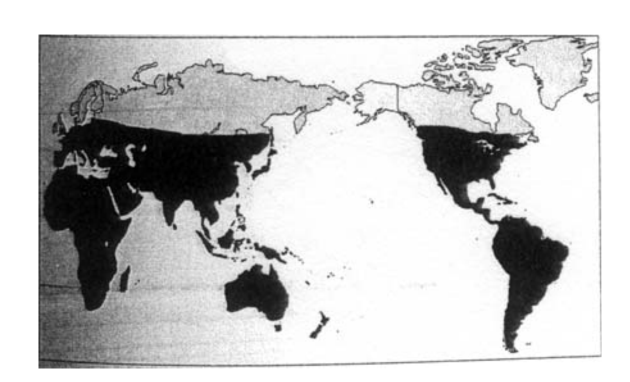
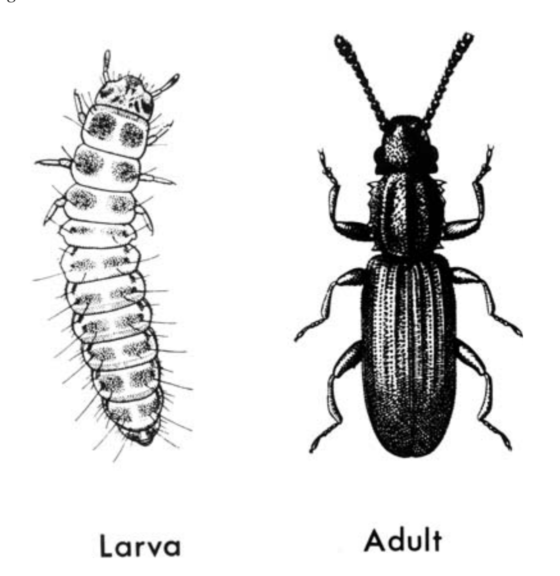
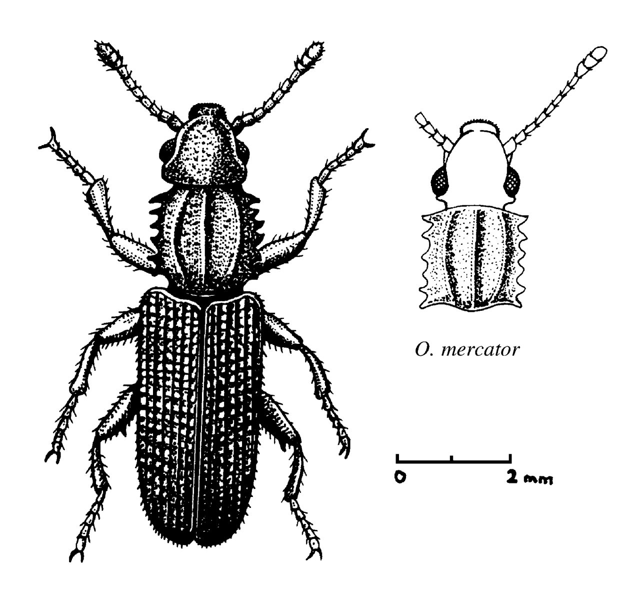


Fig. 9.163.





Epilachna spp.

Common name. Epilachna Beetles (*E. varivestis* is known as the Mexican Bean Beetle)
Family. Coccinellidae
Hosts (main). Cucurbits, and Solanaceae; in USA, beans (*Phaseolus* spp.).

(alternative). Maize, sorghum, finger millet, rice, wheat, cotton, sesame, lettuce; soybean and cowpea in N. America; and solanaceous weeds.

Damage. Both adults and larvae feed on the leaves and fruits of cucurbits and other crop plants. The leaves are eaten between the veins, sometimes being completely stripped to the midrib. Stems are often gnawed and holes are eaten in the fruits.

Pest status. A quite serious pest of many crops in Asia and Africa, and the Mexican Bean Beetle is a serious pest of various legumes in N. America.

Life history. The eggs are pale yellow, elongate-oval, with comb-like hexagonal sculpturing, and are 0.5 mm long. The eggs are laid in clusters, usually on the underside of the leaves and placed vertically. Each female lays on average 12 clusters, each with 20–30 eggs (up to 50). Incubation takes 4–5 days.

The larvae are pale yellow, covered with delicate spines when first hatched. The young larvae start feeding soon after hatching, making rows of small windows in the leaves. Fully grown larvae are dark yellow, broad, with a dark head, and strong branched spines, and 6–7 mm long. Larval development takes about 16 days.

Pupation takes place on the leaves of the host plant, and the pupa is dark yellow.

The adult beetles are oval, 6–8 mm long, reddish to brownish-yellow, but colour is variable. Each elytron is marked with a series of black spots. The adults look like typical ‘Ladybirds’ but have the distinction of being the only phytophagous representatives of this family; they are strong fliers.

The whole life-cycle takes about 35 days, and in Africa there are five generations per year.

Distribution. There are many species of *Epilachna* known, but the most important are:
E. chrysomelina (F.) – Europe, Asia and Africa (CIE map no. A409).
E. similis (Thnb.) } – Africa
E. fulvosignata Reiche } – Africa
E. sparsa (Hbst.) – S.E. Asia
E. spp. – India, S.E. Asia, USA
E. varivestis Muls. – Mexican Bean Beetle (CIE map no. A46).

Control. Sprays of dieldrin, carbaryl, methomyl, parathion-methyl, toxaphene or malathion are said to be effective against these pests.

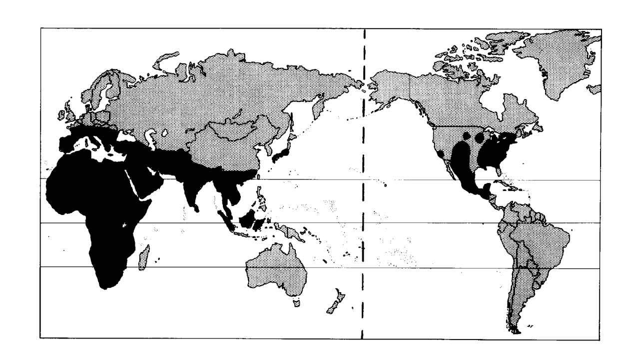
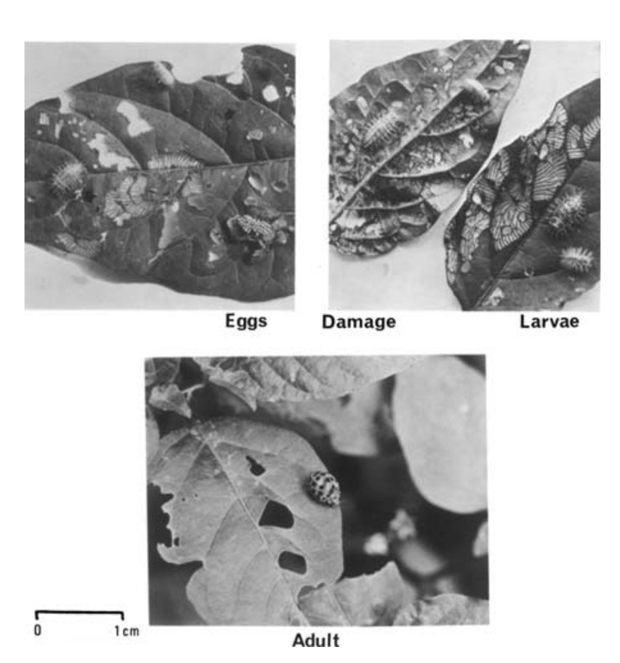


Fig. 9.164. *Epilachna* sp.; Kenya.



Gonocephalum simplex (F.)

Common name. Dusty Brown Beetle
Family. Tenebrionidae
Hosts (main). Coffee

(alternative). Many wild and cultivated plants are attacked; the species is a well-known pest of cereals.

Damage. Patches of young brown bark are chewed away from coffee stems or branches by adults Green berries are found on the ground with their stalks chewed off.

Pest status. A minor sporadic pest of coffee, especially young bushes; sometimes attacks cereals.

Life history. The eggs are presumably laid in the soil.

The larvae, which are called 'false wireworms', are found in the soil. They eat many kinds of seeds and may do slight damage to coffee roots. seedlings of maize, cotton, tobacco.

Pupation takes place in the soil.

The adult beetle is a dusty brownish-black; it is about 8 mm long, oval in outline, and flattened. The hard forewings (elytra) have longitudinal ridges. The beetles live in the mulch or the upper layers of the soil during the day. They climb up the coffee bush to feed at night, feeding principally on bark that has turned brown. Branches or stems may be completely ring-barked; more often irregular patches are chewed off, and the stalks of large green cherries are also cut through.

Distribution. Africa, S. of the Sahara.

Other species found in Asia.

Control. If coffee is to be planted in an area heavily infested with Dusty Brown Beetles it is recommended that aldrin dust should be mixed with the soil of each planting hole.

Recommended insecticidal treatment for established trees is a dieldrin spray applied round the base of each tree.

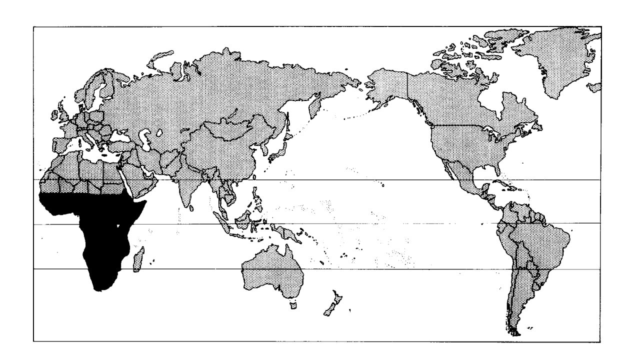
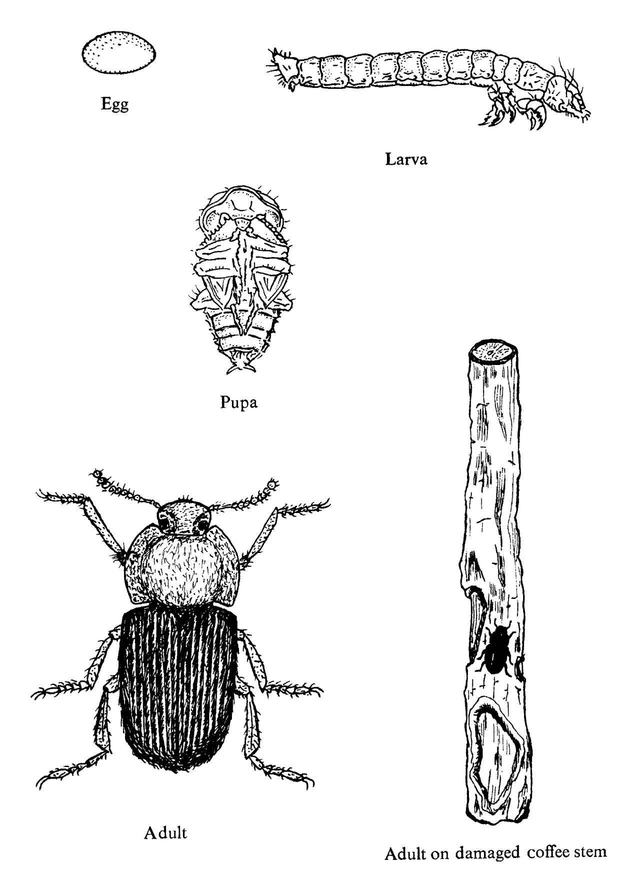


Fig. 9.165. Gonocephalum simplex (Dusty Brown Beetle); Kenya.



Tribolium spp.

(*T. castaneum* (Herbst))
(*T. confusum* (J.V.))

Common name. Flour beetles (Red and Confused)
Family. Tenebrionidae
Hosts (main). Stored cereals, flours and meals.
(alternative). Many types of stored foodstuffs.
Damage. Both larvae and adults feed on damaged grains and fragments; populations are often very large and damage may be extensive. Infestations are indicated by the presence of the small, brown, adult beetles in the grain/ produce; the larvae usually escape notice.
Pest status. These are serious pests in stored flours, meals and processed cereals; also serious secondary pests in stored grains throughout most of the world.
Life history. The eggs are small, white, sticky and cylindrical, and laid scattered in the produce. Hatching takes 5–12 days. Each female lays about 400–500 eggs.

Larvae resemble small white mealworms, with a brown head and two upturned brown pointed structures on the last abdominal segment. In stored grain the larvae live inside the grains and are responsible for most of the damage. At 25°C larval development takes about 25 days; at lower temperatures several months may be required.

Pupation takes place inside the damaged grains usually, and takes 10–17 days. The brown pupa still bears the characteristic tail-horns of the larva.

The adults are small, flattened, oblong, reddish-brown beetles, 3–4 mm in length, with head and thorax densely punctured and elytra ridged. They are long-lived, and may survive for 1–2 years, and can exist for a month without food. The adults are active and fly readily, especially in late afternoon. In dense populations the adults are cannibalistic, and will eat eggs and young larvae; populations of *Tribolium* thus tend to be well-dispersed throughout the stored grains.

At temperatures about 30°C the life-cycle may be as short as 35 days.
Distribution. These species are cosmopolitan throughout the warmer parts of the world, but *T. confusum* tends to be more temperate.
Tribolium destructor Uytt. is the Dark Flour Beetle; generally more tropical in distribution than the other two species.
Control. Intact grain, uninfested by primary pests, is generally safe from attack by *Tribolium*. However, infestation by these species is very common and often heavy, and sometimes control will be required.

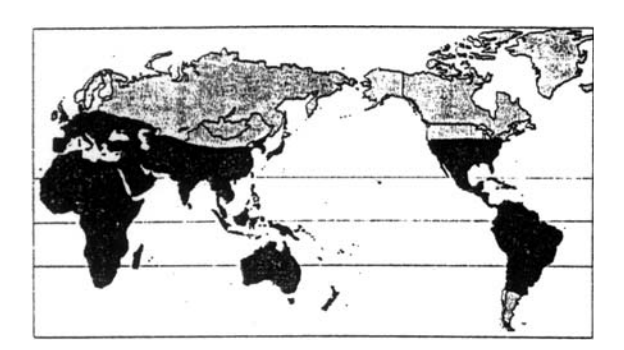
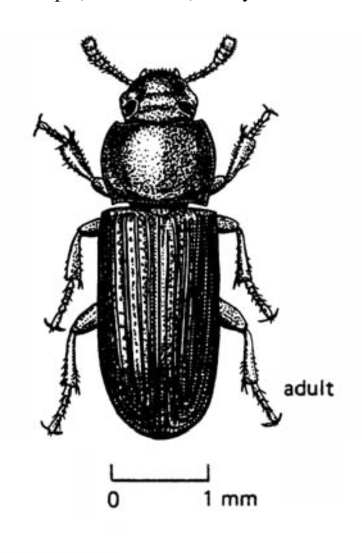
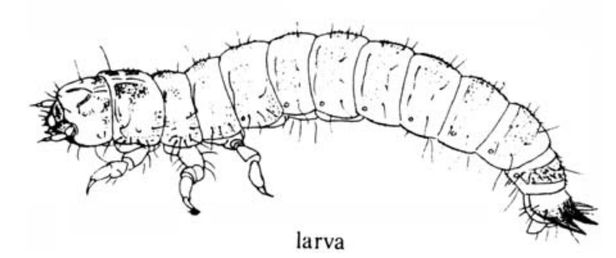


Fig. 9.166. Tribolium sp. (Flour Beetle); Kenya.





Apate spp.
monachus Boh.
indistincta Murray

Common name. Black Borers
Family. Bostrychidae
Hosts (main). Coffee species, carobs, olive, grapes, almond, peach, citrus, guava, etc. A. polyphagous pest recorded from 40 + tree species (alternative).
Damage. The beetle makes a clean cut, circular, fairly straight tunnel about 6 mm in diameter obliquely upwards in the main stem. Sawdust-like fragments drop to the ground whenever the beetle is actively boring. Heavy infestations can kill the host tree.
Pest status. A minor pest of coffee, attacking all cultivated species, although usually only a few trees in a plantation are attacked. A more serious pest in the mediterranean basin.
Life history. Egg, larval, and pupal stages have not been recorded from coffee. They occur in the trunks and dried branches of shade and other trees.

The adult beetle is black and nearly 20 mm long. It is rather square at the front end; the head is not visible from above, being deflexed under the thorax. Development in Israel takes upto 3 years.
Distribution. Tropical Africa, N. Africa, S. Africa, Madagascar; Sardinia, Corsica, Spain, Syria, Israel; W. Indies, and tropical S. America.
Control. The usual recommendation is to spear the beetle in its tunnel by pushing a springy wire (e.g. a bicycle spoke) up the hole! This is usually the best method.

Alternatively, a plug of cotton wool can be soaked in dieldrin liquid and pushed up the tunnel.

It is advisable to clear away the sawdust-like frass from the base of the tree when control measures are applied; if they fail to kill some of the beetles then fresh frass will be seen on the ground again after a few days. Phytosanitation practices are strongly recommended

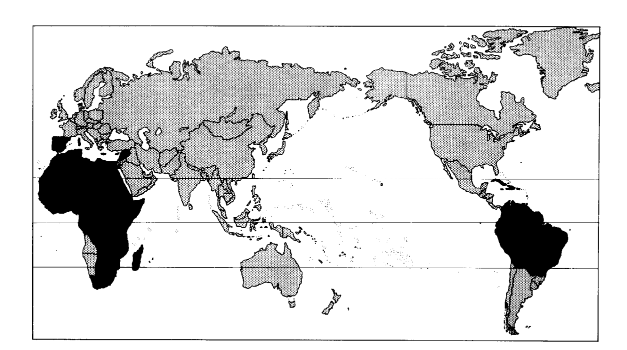
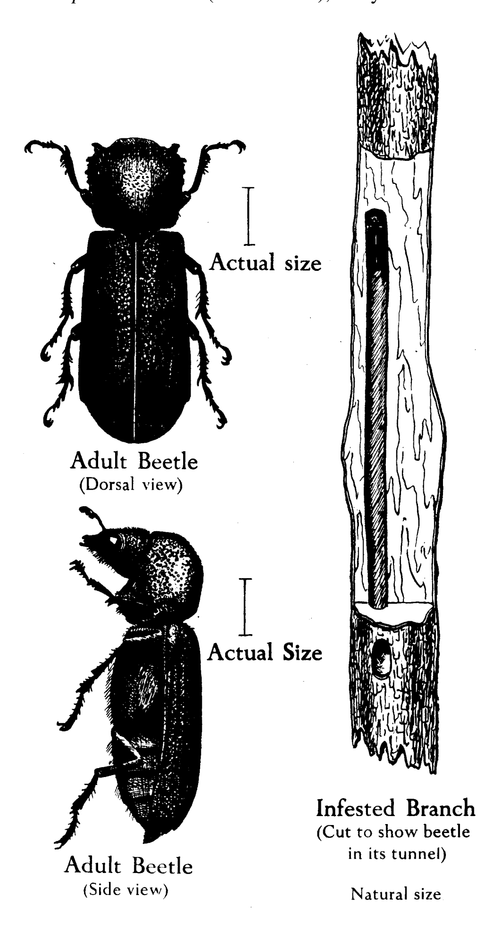


Fig. 9.167. Apate monachus (Black Borer); Kenya.



Prostephanus truncatus (Horn) (Larger Grain Borer)

Pest status. A very serious pest of recent origin, after having been accidentally introduced into East Africa; now a serious threat to smallholder peasant farmers in Africa, especially since it can attack relatively dry grain in storage. A minor pest in native Central America.

Produce. A pest of stored maize and dried cassava tubers in on-farm stores mostly. Softer grains are especially vulnerable. It can damage a wide range of grains and seeds, but can only breed on maize and cassava.

Damage. Adults bore the grains and cassava and create a lot of dust. Females lay their eggs in tiny chambers cut at right angles to the main tunnel; some larvae develop inside the grains, and some in the dust. Thus both adults and some larvae feed on the produce and cause damage. Sometimes structural timbers may be bored. Grains are eventually hollowed out, and cassava roots bored to such an extent that they are reduced to dust internally (as a hollow shell); cassava losses of 70% after only 4 months' on-farm storage have been reported. The damage is done by the insects biting and chewing with their mandibles.

Life history. Eggs are laid in short side tunnels inside the grains in store; each female lays 50–200 or more eggs over a 12–14 day period; hatching occurs after 3–7 days at 27°C, or 4 days at 32°C.

Larvae are white and scarabaeiform with distinctly larger thoracic segments; they feed mostly on the dust (flour), and they moult 3–5 times (usually 3). Fully-grown larvae measure 4 mm, and development takes some 27 days at 32°C and 80% RH, when fed on maize grain. At 32°C, larvae developed when the grain mc was as low as 10.5%, and the time required was increased by 6 days; field studies in Tanzania showed maize with mc as low as 9% being heavily infested. Pupation occurs inside a pupal case in the frass and powder, or inside the grains, and requires 5 days at 32°C. Adults are small dark cylindrical beetles, 3–4 mm long; the large hooded prothorax is densely and coarsely tuberculate; antennae of 10 segments have a large loose club of three segments. Their characteristic feature is that the elytral posterior declivity is steep, flat, and limited by a distinct carina posteriorly and the surface is tuberculate. Adults fly and may start field infestation of maize prior to harvest; they usually live for 40–60 days.

The life cycle on maize grains can be completed in 32 days at 27°C and 70% RH (25 days on cobs at 32°C), whereas on cassava it is recorded taking 43 days (Hodges, 1986).

Distribution. Native to Central America, it has spread to South America, southern USA, and in the 1970s was accidentally introduced into Tanzania, and has since spread to Kenya, and in 1984 was found in Togo. The spreading distribution is a serious threat to smallholder farming in tropical Africa.

Natural enemies. A number of predacious and parasitic insects are found in infestations, but their precise relationships are not yet known – the topic is the subject of extensive research in the hope that this pest might be controlled biologically.

Control. The shelling of maize prior to storage does reduce the extent of the damage, as also does the growing of the old flinty varieties rather than the new high-yielding softer grained varieties. Male-produced aggregation pheromone is being used for population monitoring. ICI recommend 'Actellic Super', a mixture of pirimiphos-methyl and permethrin, for chemical control. Other chemicals currently being used are permethrin, deltamethrin and fenvalerate.

Several natural enemies are being released in Africa in an attempt to control populations – with some success. See Dick (1988)

Fig. 9.168. Prostephanus truncatus (Larger Grain Borer) (Coleoptera; Bostrychidae); dorsal view of adult beetle showing abrupt posterior termination (courtesy of ICI).



Rhizopertha dominica (Fab.) (Lesser Grain Borer)

Pest status. A serious pest of stored grains and other foodstuffs worldwide; a primary pest of stored grain; occasionally recorded infesting ripe cereals in the field. An important penetrative species.

Produce. Cereal grains in store, cereal products, flours, and dried cassava; to some extent pulses may also be eaten.

Damage. Eating of the grains and food material is the main damage; on intact grains, the adults show a preference for the germinal region; such selective damage can be quite serious economically.

Life history. Each female lays 200–500 eggs, either dropping them loosely into the produce or else laying them in crevices on the rough surface of seeds. More eggs are laid at higher temperatures, and oviposition may continue for up to 4 months. Hatching occurs after a few days.

The larva is white and parallel-sided, with a small head and quite prominent legs; the first instar has a distinctive median posterior spine. There are 3–5 larval instars, and development takes about 17 days (34°C and 70% RH) on wheat. Development is more rapid on cereal grains than on flours. Newly hatched larvae may feed on flour dust created by the adult beetles, but usually bore into the whole grains, which are eventually hollowed out. Larvae can develop on grain with a low mc – at 34°C they can develop on grain with a mc as low as 9%, although mortality is high. It is clear that there is interaction between mc and temperature in controlling the rate of larval development.

Pupation usually takes place inside the damaged grain, and takes 3 days at 34°C and 70% RH.

Adults are small (2–3 mm) dark cylindrical beetles, with the head hidden under the large hooded, tuberculate prothorax. Antennae are 10-segmented, with a large, loose, 3-segmented club. The abdominal sternites are used for sexual distinction. The elytra have rows of punctures with short setae; apically the elytra are rounded, and there are no other ornamentations, nor a terminal carina. Adults are long-lived, feed extensively, and fly quite well. They are seldom obvious in infestations as they are usually inside the infested grains, together with the larvae.

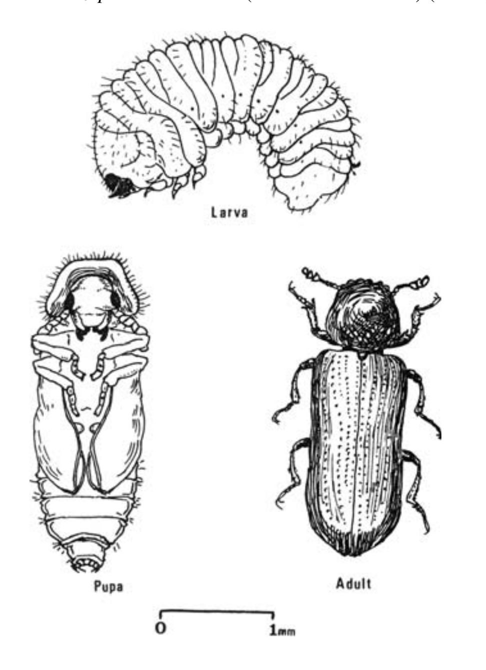
The life cycle is completed most rapidly when feeding on grains at a high temperature (3–4 weeks at about 34°C and 70% RH). Development is most rapid on broken kernels, then whole grains; flours are not preferred.

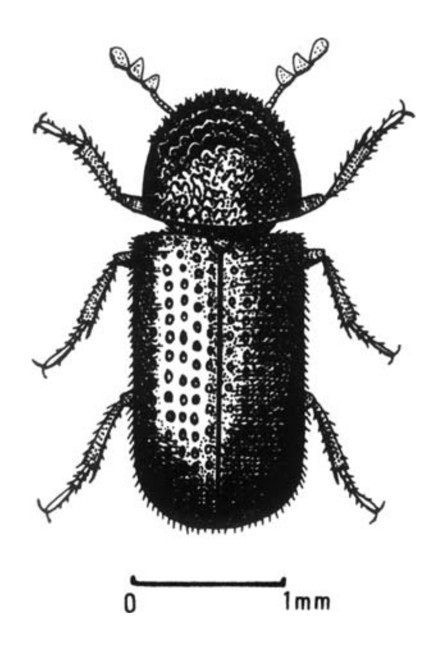
Distribution. Basically a tropical species, but cosmopolitan throughout the warmer parts of the world, and occurring in heated stores in temperate regions. During World War 1, infested wheat from Ausralia distributed this pest throughout the USA and many other countries.

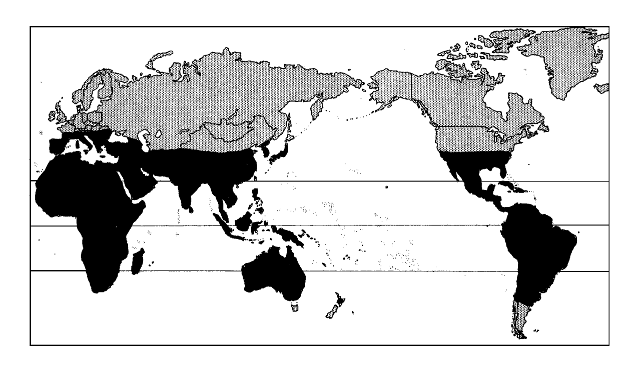
Natural enemies. The usual stored product beetles parasites (Pteromalidae) are recorded, namely *Lariophagus, Chaetospila* and *Anisopteromalus*.

Control. Population monitoring for this pest usually relies on sack sieving and spear sampling, as the adults tend to be sedentary and will not move to traps. There is now a male-produced aggregation pheromone that might prove to be effective. Pirimiphos-methyl and various pyrethroids are effective pesticides; fumigation is also effective.

Fig 9.169. Rhizopertha dominica (Lesser Grain Borer) (Coleoptera; Bostrychidae), adult beetle, dorsal view.







Stored products beetles (and other pests)

As listed on page 658, the more important pests of stored products are the few moths in the Pyralidae, some mites (Acarina), and a miscellany of beetles that belong to several unrelated families. The different types of damage inflicted by these different insects are mentioned on page 75. It should be emphasized that in any study of post-harvest crop losses that the effects of rodents (the synanthropic rats and mice) in many rural situations are extremely important, as is granivorous bird damage on the ripening crop in the field, for all the small-grained cereals.

So far as the insects and mites are concerned, in the damage done, and in various aspects of infestation, they are able to be considered collectively. Certainly the methods of controlling insect populations, and of minimizing damage to the stored products, are equally applicable to the moths and their larvae as to the beetles.

Stored produce infestation control

In any produce infestation control programme the approach should ideally be for several phases simultaneously, the major aspects being:

(1) **sound buildings:** if there are holes or cracks in the walls, and if doors do not fit properly, or windows are broken, then access for rats, mice, and insects is made easy. Also fumigation will not be effective if the building cannot be properly sealed.

(2) **use of containers:** on a large scale this would include silos that are specially designed for bulk storage of grain or pulses, and that hold many tonnes of produce, and could also include the underground silos used for long-term grain storage in many countries as part of the national strategic (famine) reserves. Some of these silos, which are usually air-tight, are hermetically sealed, sometimes with a toxic or inert gas pumped into the top prior to sealing (carbon dioxide or nitrogen). Even if air-filled, such silos are effective in that after sealing the small amount of air present is soon depleted of oxygen by the insects present which then soon suffocate.

Shipment of some bulk produce is now being effected through the use of freight containers; well-made containers should be virtually air-tight and produce may be fumigated after being packed. However, in practice, many of the containers being used for international transport of agricultural produce are damaged slightly and no longer gastight, so attempts at fumigation are often less than successful.

The use of clean sacks for bagged produce is of prime importance, but will be referred to in (6).

(3) **store hygiene:** this refers to general cleanliness, removal of debris, old sacks, spilled grain, etc., which should be burned or otherwise destroyed. The cleaning of storage premises using industrial vacuum cleaners will also remove insect and mite eggs from the crevices; ordinary sweeping will usually leave mites on the floor surface.

(4) **clean produce:** all produce should be inspected prior to admittance into a store to ensure that only uninfested material is brought in. Some pests, for example *Sitophilus* weevils on maize and bruchids on pulses, etc., are naturally found in small numbers in field infestations, and care has to be taken to ensure that the harvested crop is not already field-infested. Infested produce should be treated in a special gas-tight fumigation chamber prior to admittance into a store.

(5) **drying and cooling:** at the time of harvest most grain and pulse crops are somewhat moist and require drying prior to storage. In more simple situations traditional air-drying is practised, but this is fraught with problems owing to the vagaries of the weather, and a recent trend is for bulk cleaning and drying in regional stores. Usually the grain is first screened to remove trash and then dried. The longer the storage time anticipated then the lower the moisture content of the grain should be. Wheat should never be stored at all at moisture levels exceeding 16%; at levels of 14% or less most insects show a marked reduction in rate of development. At moisture levels of above 13% *Aspergillus* and *Penicillium* readily develop. With most (but not all) stored products pests it is well known that at low relative humidities their rate of development drops significantly.

Cooling the produce to a safe level of about 15°C also slows down the rate of insect development greatly, and for some serious sub-tropical pests development will cease altogether at these temperatures. The temperature threshold for development for *Cryptolestes ferrugineus* is 20°C; for *Lasioderma serricorne* it is 19°C; for *Rhizopertha dominica* it is 18°C; for *Oryzaephilus* it is 17.5°C; but for *Sitophilus granarius* this temperature is 13°C.

(6) **pesticide treatment:** this is done in several different ways:

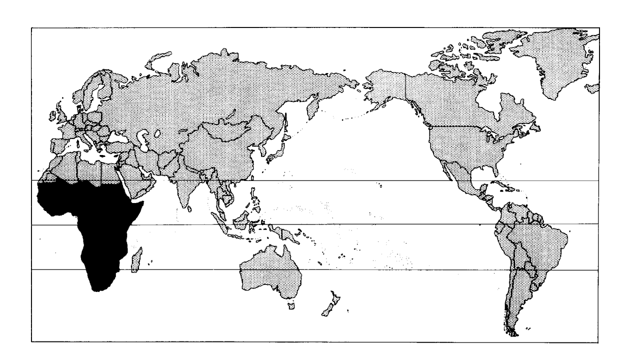
(a) *treatment of buildings, containers and sacks*: the empty buildings need fumigation or spraying to kill eggs and larvae (and adults) that may be hiding in crevices and cracks. Sacks likewise need regular cleansing treatment. In some species pupation takes place in a cocoon attached to a solid substrate such as a crevice wall or sack. Piles of sacks may be easily fumigated in sealed bins using a mixture of ethylene dichloride and carbon tetrachloride, poured over as a liquid.

(b) *fumigation*: provided that the granary or the storage bins are reasonably gas-tight, on-farm fumigation of grains may be carried out using the following; a 1:1 mixture of ethylene dichlo-tablets that release phosphine gas on contact with air moisture. Methyl bromide is very effective, but because of its toxicity it may only be applied by a registered operator, and its use is generally restricted to large commercial stores. Most silos are reasonably gas-tight and fumigants can be added after the silo is filled and prior to sealing. Bulk bag fumigation can be carried out under fumigation sheets, but the sheet edges have to be adequately sealed for effective treatment. Most large storage premises have a fumigation chamber, preferably large enough for a loaded lorry to be driven in, for disinfestation purposes. Successful fumigation depends in part on the toxicity of the gas employed, its concentration, and the duration of exposure. Penetration of bulk grain, or stacks of bags, may be quite a slow process, and so usually about three days duration is required. For more details about fumigation see Monro (1980).

(c) *pesticide admixture*: in buildings known to be regularly infested, or in situations (countries) of known high risk, the addition of insecticides as either spray or dusts to the grain as it passes into storage may be worthwhile. The chemicals usually recommended nowadays include malathion (both as e.c. and dust), pirimiphos methyl (both as e.c. and dust) and fenitrothion. These are also the chemicals recommended for the general spraying or treatment of buildings and storage premises, and they usually kill beetles, moths and mites. Pesticide admixture to stored grain is now banned in the USA and some other countries.

Coryna spp.

Common name. Pollen Beetles
Family. Meloidae
Hosts. Flowers of pulse crops, cotton, and many flowering plants.
Damage. The adults eat the pollen out of the open flowers, often destroying the anthers in the process.
The larvae are not pests.
Pest status. A widespread and common pest, but not economically serious, found on many flowering crops. It can be of importance on research stations by interfering with cotton boll-setting in breeding material, and similarly on pulse crops.

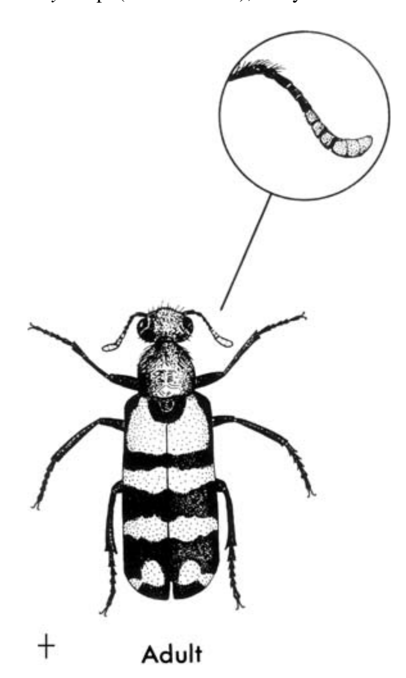


Life history. As with *Mylabris* spp., the eggs are laid in the soil, developing initially into very active and mobile triungulin larvae which seek out eggs of Orthoptera. Older larvae become eruciform, sluggish, with a large body and reduced legs.

Pupation is in the soil.

Adults are elongate, 10–16 mm long, with a black hairy head and thorax, club-shaped antennae with a yellowish club, smooth flexible elytra with three transverse yellow and black stripes. The coloration of the distal segments of the antennae is an important specific character in this genus.
Distribution. Tropical Africa.
Control. For control see *Mylabris* spp. (p. 295).

Fig. 9.170. Coryna sp. (Pollen Beetle); Kenya.



Epicauta spp.

Common name. Striped Blister Beetles, etc.
Family. Meloidae
Hosts (main). Pulse crops, especially groundnut and soybean, and forage legumes.

(alternative). Tomato, potato, eggplant, capsicums, beet, onions, cucurbits and many

Damage. garden plants and ornamentals often occurs in very large numbers and may completely defoliate a crop; the beetles feed on the leaves, making large irregular-shaped holes in the lamina. The larvae are not pests.

Pest status. A sporadic pest of pulse crops, occasionally important, but quite common in E. Africa, and other species are found in other parts of the tropics.

Life history. Eggs are laid in holes in the soil, in clusters of 100 or more.

As with other Meloidae the larvae are predators on the egg-pods of grasshoppers. The triungulins hatch after 5–8 days.

The adult is a black blister beetle 13–20 mm long, with large eyes, and a pale whitish stripe running down the dorsum from the head and thorax and thence round the edges of the elytra. There is also a whitish stripe along the centre of each elytron extending nearly to the posterior apex, and transverse white stripes on the abdomen. The stripes are bands of white scale-like setae, and there are white setae on the legs.

Distribution. This genus of blister beetle is probably best represented in the New World where the most species are recorded, but some are found in Africa and Asia. The more important species are probably as follows:
Epicauta aethiops (Lat.) – (Grey Blister Beetle) N. Africa.
E. albovittata (Gestro) – (Striped Blister Beetle) E. Africa.
E. maculata (Say) – (Spotted Blister Beetle) Canada and USA.
E. pennsylvatica (DeG.) – (Black Blister Beetle) Canada and USA.
E. gorhami Mars. – (Striped Blister Beetle) China.
E. rufipes (III.) – (Red-headed Blister Beetle) Indonesia
E. tibialis Waterhouse – (Black Blister Beetle) China
E. vittata F. – (Striped Blister Beetle) Canada, USA and S. America.
E. limbatipennis – E. Africa

Control. Chemical control is difficult because the pest has a high level of natural resistance to insecticides such as DDT and γ-BHC, but high dose levels of dieldrin and parathion usually give a good kill.

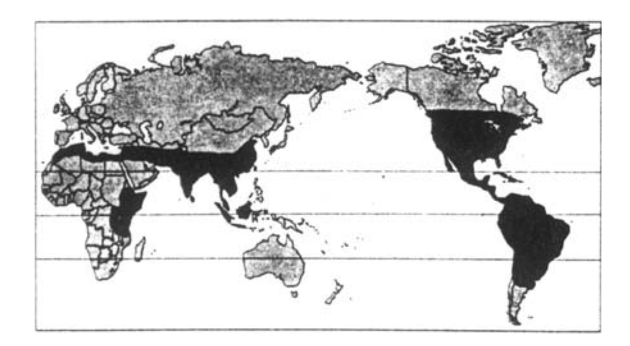
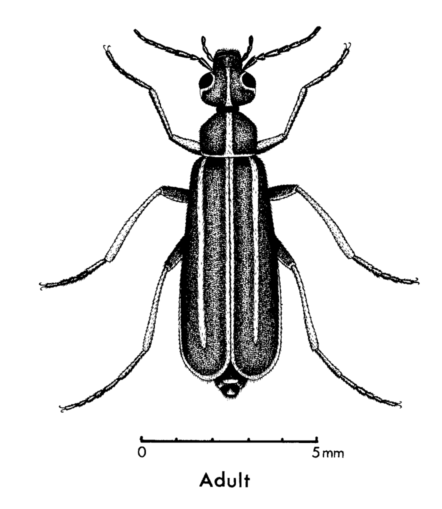


Fig. 9.171. Epicauta albovittata (Striped Blister Beetle); Kenya.



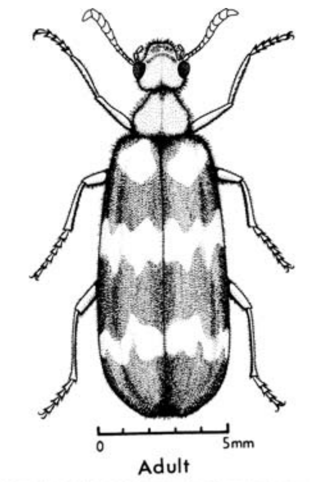
Mylabris spp.

Common name. Blister Beetles (Flower Beetles)
Family. Meloidae
Hosts (main). Pulse crops
(alternative). Cotton, and many flowers and ornamentals (e.g. *Hibiscus*).
Damage. The flowers are eaten by the adult beetles, causing a loss of pods in leguminous crops and conspicuous damage to various flowering ornamentals.
Pest status. A widespread and common, but not commercially serious, pest of many flowering crops.
Life history. Eggs are laid in the soil in batches (2,000) hatch into very active triungulin larvae which feed on egg pods of Orthoptera. The later larval stages are often sluggish with a large body and reduced legs. An abundance of meloid beetles has often been noted following locust invasions.

Pupation takes place in the soil.

The adults are large beetles, 25–35 mm long, with a bright conspicuous red (or yellow) and black patterned coloration. They are rather sluggish in behaviour but are strong fliers. If handled the adults exude an acrid yellow fluid containing cantharidin, the effect of which upon the skin accounts for the common name of 'blister beetle'.
Distribution. Africa, India, Bangladesh, Sri Lanka, and S.E. Asia; several species are known.
Control. The adult beetles are difficult to control because of their mobility; also the damage done is usually only slight and so chemical control is seldom warranted commercially, but it is expected that dieldrin and parathion sprays might be effective. Carbary (0.2% spray and 5% dust) and endosulfan as a 0.1% spray are successful.

Fig. 9.172. Mylabris sp. (Blister Beetle) Kenya and S. China



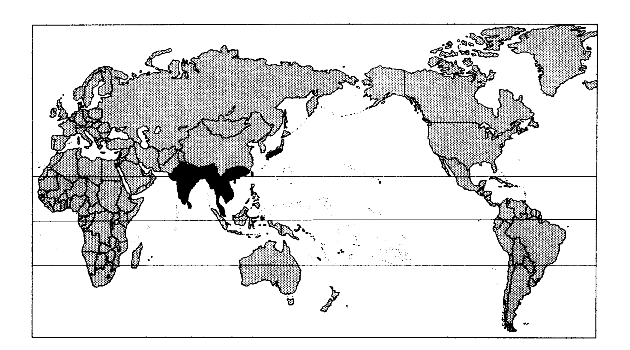


M. cinchorii on flowers of pigeon pea

Anoplophora spp.
A. chinensis (Forst.)
A. malasiaca Thom.
A. versteegi (Ritz.)

Common name. Citrus Longhorn Beetles
Family. Cerambycidae
Hosts (main). *Citrus* spp.
(alternative). Other members of the Rutaceae and mango.
Damage. The feeding larvae tunnel in the branches and trunks just under the bark, and occasionally they bore deep into the heartwood. Small trees, and branches of larger trees, are often killed.
Pest status. A serious pest of *Citrus* in S. China, and India.
Life history. Details are not known, but can be presumed to be similar to other Cerambycidae. Larval development takes a year.

The adult is a distinctive longhorn beetle, with long antennae and striking black and white body coloration, or black and orange spots, or pale blue with black bands.



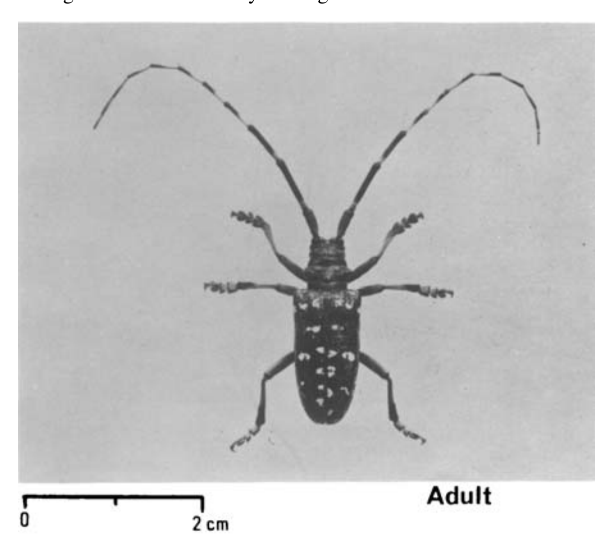
Distribution. Recorded from Japan, E.&S. China, Indo-China, India and Malaya.
Control. Heavily infested branches should be cut out and burned to destroy the larvae and pupae within. Spraying the trunks and branches with dieldrin has in the past proved to be of some value. In some cases a mixture of dieldrin and kerosene has been injected into the frass holes to kill the boring larvae. A combination of these three methods usually gives adequate control.

After any chemical treatment has been applied the old frass under the infested tree should be removed so that any new frass to be expelled will be immediately obvious, and the chemical treatment can be repeated. Sometimes it is recommended that a marker dye (methylene blue for example) be added to the dieldrin solution so that it will indicate the extent of the solution penetration within the larval tunnel system.

Fig. 9.173. Anoplophora chinensis (Citrus Longhorn Beetle); S. China.



Young *Citrus* stem killed by feeding larvae

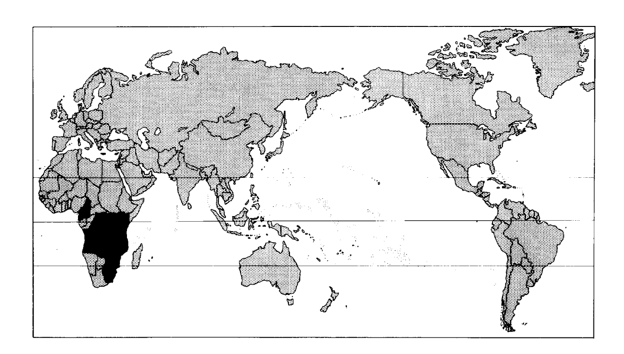


Anthores leuconotus Pasc.
(= *Monochamus leuconotus* (Pasc.))

Common name. White Coffee Borer
Family. Cerambycidae
Hosts (main). Coffee, particularly *arabica*.
(alternative). Various wild Rubiaceae (shrubs).
Damage. Attack is indicated by a yellowing of the foliage and eventual death of the trees. Wood shavings extruded by the larvae from their burrows in the bark are diagnostic, as are the round exit-holes of the adult beetles in the trunks of the trees.
Pest status. A serious pest of *arabica* coffee below about 1700 m in Africa.
Life history. Eggs are inserted beneath the bark of the tree usually within 0.5 m of the ground. They require three weeks to hatch.

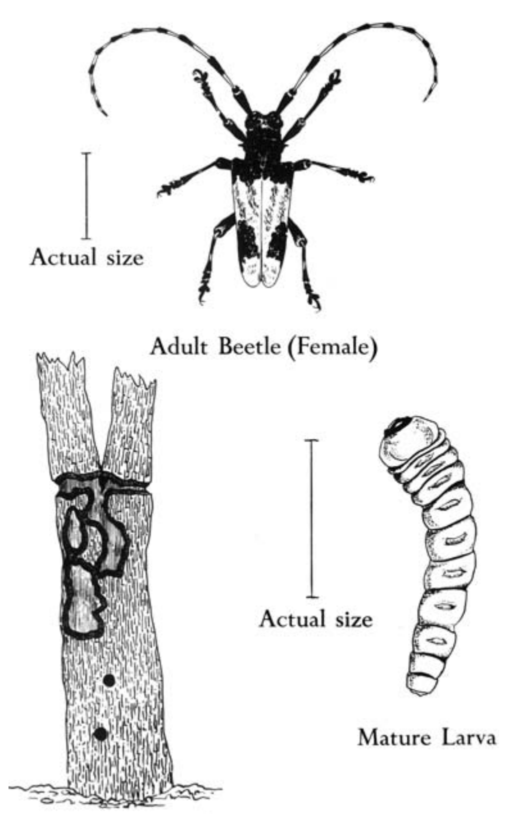
The young larvae bore just under the bark of the tree downwards from the point of insertion of the eggs. In these early stages the most serious damage, in the form of ring-barking, is done. Complete ring-barking does not invariably occur. The larvae continue downwards towards the ground, under the bark, and usually penetrate the wood of the tree at the junction of a lateral root with the stem of the tree. The later instars bore in the wood cylinder. There are thought to be seven larval instars, and the larval stages last about 20 months.

The full-grown larva excavates a large chamber within the trunk in which pupation takes place; the duration of the pupal stage varies between 2–4 months.



Adult beetles are about 30 mm long; they are greyish with a dark head and thorax and dark markings near the end of the wing cases. At the start of the rains they emerge from the tree trunk by cutting circular holes to the exterior, which are about 8 mm in diameter. The beetles do little damage and feed only on the bark of the branches. A single female beetle has been known to lay 23 eggs.
Distribution. The southern half of Africa only (CIE map no. A196).
The White Coffee Borer of India is *Xylotrechus quadripes*; other species of *Xylotrechus* bore in mango, walnut and mulberry.
Control. The recommended insecticide is dieldrin with added methylene blue dye as a marker. The mixture should be applied to the trunks of the trees from ground level to a height of about 0.5 m. Application can be by spray lance or brush. The best time is just before the onset of the rains. The spray should be repeated one year later, and after that every second year. The adult beetles are killed when they touch sprayed bark during oviposition or emergence.

Fig. 9.174. Anthores leuconotus (White Coffee Borer); Kenya.



Apriona spp.

Common name. (Mulberry/Apple) Longhorn Beetles
Family. Cerambycidae
Hosts (main). Mulberry, apple.
(alternative). Fig, jackfruit, peach; wild species of *Ficus* and other Moraceae.
Damage. The larvae tunnel in the branches and tree trunk, just under the bark, and sometimes into the heartwood; in small branches they bore down the centre. Frass expulsion holes are made from which sap often exudes. Heavily attacked trees may die, especially as stressed trees are preferred as hosts.
Pest status. Widespread pests in Asia, causing spectacular damage; not often serious pests; frequently stressed or sickly trees appear to be favoured as hosts.
Life history. Eggs are laid in crevices in the bark, and hatch after about 7–10 days. The larvae burrow in the sapwood under the bark, making frass holes at intervals. Larval development under warm conditions takes 9–10 months, but under cooler conditions it is thought that nearly two years may be required. Pupation takes place at the end of the larval tunnel which is blocked by wood fragments.

The adults emerge in the spring; they are large, dark grey beetles, 4–6 cm in length, with conspicuous blackish tubercles at the bases of the elytra. The males are distinctly smaller than females, but have longer antennae. Both adults feed on tree bark or foliage, and they may live for several months.

In warmer regions the life-cycle is probably univoltine, but farther north it is likely that two years are required for complete development.
Distribution. The main species concerned as pests are as follows:
Apriona cinerea Chevr. – (Apple Stem Borer) India.
A. germari (Hope) – (Mulberry Longhorn Beetle) India, throughout S.E. Asia to S. China.
A. japonica Thom. – (Mulberry Borer) Japan.
A. rugicollis Chevr. – also from mulberry; India.
Control. When control is required it has been found that spraying the tree trunk with dieldrin or parathion will kill eggs and young larvae. With established larvae injecting the tunnel with dieldrin/kerosene has been effective.

After tunnel treatment it is recommended that all old frass be removed from under the tree, so that any new frass expelled is immediately obvious and the chemical treatment can be repeated.

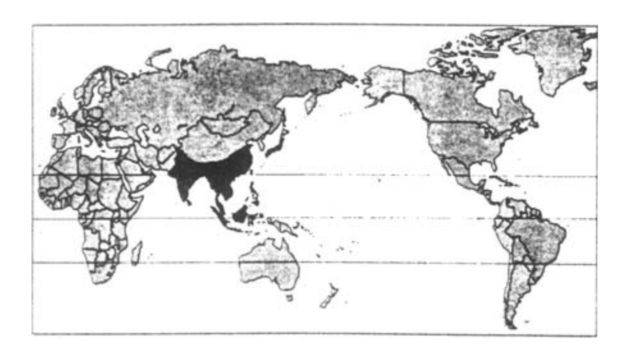
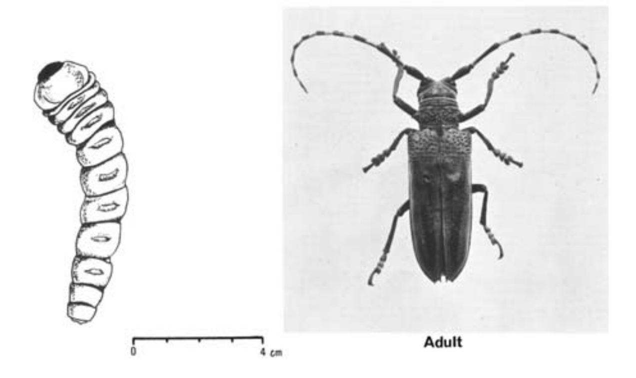


Fig. 9.175. Apriona germari (Jackfruit Longhorn Beetle); S. China.





Batocera rubus (L.)

Common name. White-spotted Longhorn Beetle.
Family. Cerambycidae
Hosts (main). Fig, mango, jackfruit, cocoa, kapok, rubber.
(alternative). Various other tree species.
Damage. The larvae burrow through the sapwood under the bark of the trees, either on the trunk or on the main branches. Frass expulsion holes are made at intervals making and sometimes sap oozes out of the holes, obvious symptoms. On damaged branches the foliage may die and fruitset will be impaired.
Pest status. A widespread pest, together with its larger relative (*B. rufomaculata*), are frequently encountered in fruit trees and various ornamentals but seldom a serious pest.
Life history. Eggs are laid singly in the bark of the tree, up to 200 in total, into small cuts made by the female's mandibles. The young larvae bore straight into the wood, feeding in the vascular tissues of the, eventually making long irregular tunnels in the sapwood. In multiple infestations the flow of sap and is interrupted, which has obvious adverse on the tree. Pupation takes place within the tunnel system, usually just under the bark.

The adult is a greyish-brown beetle, about 4 cm in body length, with a series of conspicuous spots on the elytra. The adults live for several months and feed on the bark of the tree to some extent.

The complete life-cycle could be as short as one, but might be two years.
Distribution. From India through S.E. Asia to China, also Mauritius and the W. Indies.
Control. If required, then the control methods given *Anoplophora chinensis* (p. 296) should be employed.

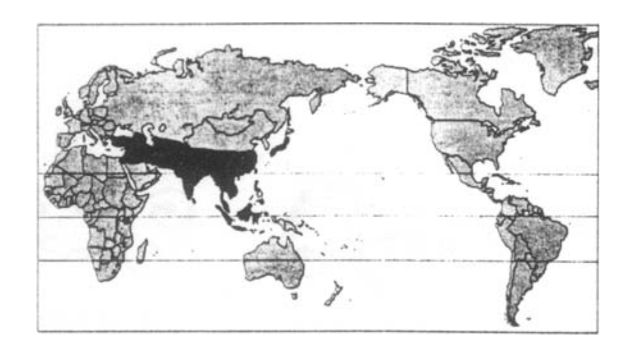
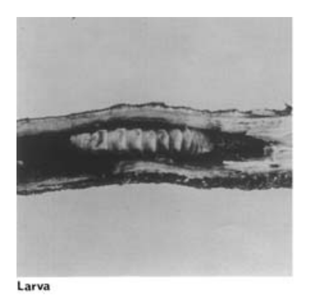
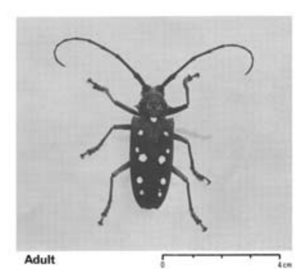


Fig. 9.176. Batocera rubus (White-spotted Longhorn); S. China.







Batocera rufomaculata (De Geer)

Common name Red-spotted Longhorn Beetle
Family Cerambycidae
Hosts (main). Fig, mango, guava, jackfruit, pomegranate, apple, rubber and walnut.

(alternative). In India recorded from more than 100 different host plants.
Damage The larvae tunnel through the sapwood and, because of their size, they make large tunnels, which interfere with sap flow and affect foliage and fruit production. Heavily attacked trees may die.
Pest status A serious pest of Edible Fig, and of regular occurrence on the other fruit trees mentioned.
Life history The female beetle cuts the tree bark and lays eggs singly into these cuts; laying a total of up to 00 eggs. On hatching the larvae start to tunnel into the sapwood of the trunk or branches. Larval development takes probably two years. As a very large species, the larval tunnel, measuring 2–3 cm in width, is correspondingly large and very damaging to the tree.

The adult beetles emerge in the spring (in S. China), they are especially large and measure up to 70 mm in body length, with very long antennae. In the spots on the elytra and the prothorax are bright red (hence the name) but after death they fade to white or pale yellow.

It is thought that the life-cycle takes two years to complete.
Distribution. This species is recorded from S. China and S.E. Asia, through India to the eastern Mediterranean. Wyniger (1962) records it from E. Africa, but the specimen illustrated looks rather like *Apriona*!
Control. As suggested for *Anoplophora chinensis* (p. 296).

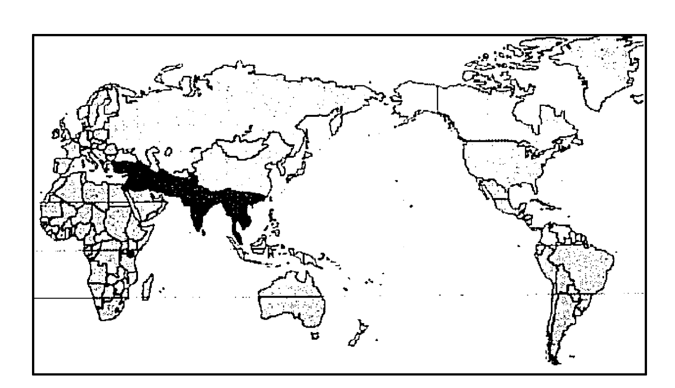
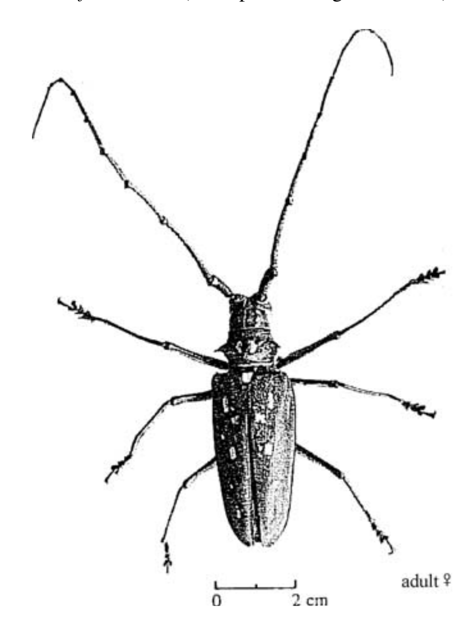


Fig. 9.177. Batocera rufomaculata (Red-spotted Longhorn Beetle)



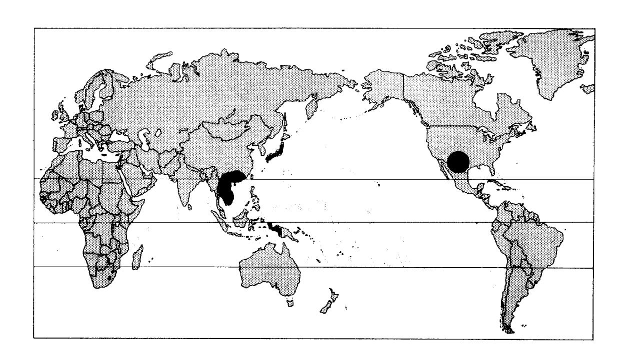
Larva in situ in tree branch

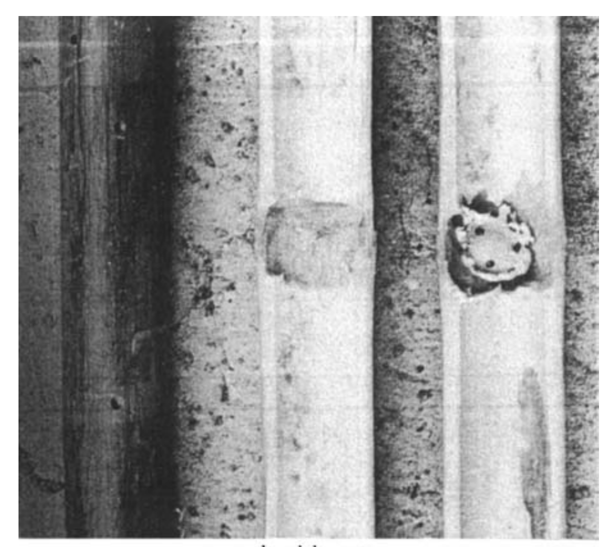


Chlorophorus annularis (F.)

Common name. Bamboo Longhorn Beetle
Family. Cerambycidae
Hosts (main). Bamboo s
(alternative). Sugarcane.
Damage. The tunnelling larvae bore through the internode walls and through the nodes of bamboo stems, and generally inside the stem of sugarcane.
Pest status. A common Oriental species of longhorn to be found regularly in various species of bamboo, and occasionally in sugarcane, but not of particular importance.
Life history. Details are not known at present.

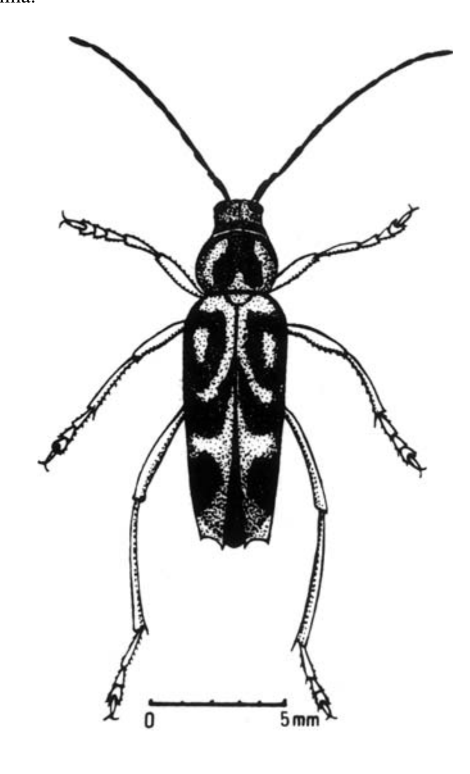
The adult beetle is quite small and slender, some 10–16 mm in length, with yellow and black markings; the distal ends of the elytra are deeply emarginate, ending in two spines. This species regularly emerges in domestic premises from bamboo stems made into furniture. Adults have emerged from pieces of dried bamboo that have been stored for longer than a year, so it probably has a two-year lifecycle.
Distribution. An Oriental species from S. China and Indo-China, and Japan, W. Irian, and the USA. Also in Japan in *C. japonicus* (Chev.)
Control. Normally not required.





larval damage

Fig. 9.178. Chlorophorus annularis (Bamboo Longhorn Beetle); S. China.



Dirphya spp.
D. nigricornis (01.)
D. princeps Gord.

Common name. Yellow-headed Stem Borers
Family. Cerambycidae
Hosts (main). Coffee, mainly *arabica*.
(alternative). Other wild woody Rubiaceae.
Damage. Attacked plants have wilted tips to the primaries; a series of holes down one side of a branch or main stem; broken branches are common.
Pest status. Normally a minor pest of *arabica* coffee, but severe attacks have occurred locally.
Life history. Eggs are laid singly near the tip of a branch under a small flap of green bark.

The larva is red or brown when young. On hatching it bores into the green shoot, causing it to wilt. Later it bores down the primary towards the main stem, making a flute-like series of holes to the outside. Through these holes it throws out its saw-dust-like frass. Burrowing continues right down the main stem. The mature larva is yellow or orange and about 50 mm long. The duration of the larval period is about ten months.

The pupa is about 30 mm long. It is found in a cell excavated by the mature larva usually near ground level. The pupal period is about two months.

The adult is a slender beetle about 25 mm long with long black antennae. The body is generally brown but the head, thorax and about the first quarter of the wing cases are orange or yellow. Most of the beetles emerge during the rainy seasons.
Distribution. Only E. Africa and Malawi.
Control. Wilted primaries should be cut off and destroyed, and old heads should be burned.

For chemical control it is suggested that the lowest frass hole should be enlarged and (usin a pen filler or oil can) a mixture of dieldrin and kerosene (1:100) or water, squirted in; pyrethrins or paradichlorobenzene can be used.

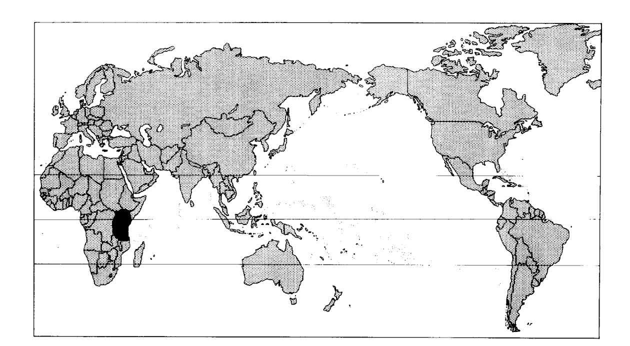
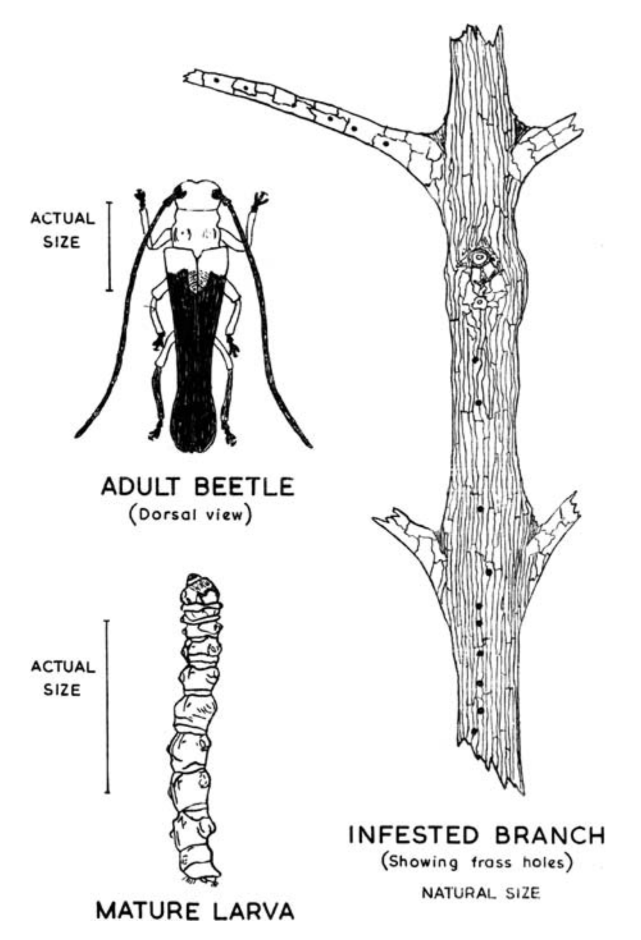


Fig. 9.179. Dirphya nigricornis (Yellow-headed Stem Borer); Kenya.



Paranaleptes reticulata (Thoms.)

Common name. Cashew Stem Girdler
Family. Cerambycidae
Hosts (main). Cashew

(alternative). All wild members of the family Bombacaceae (e.g. Baobab) are probably Stem Girdler hosts. *Hibiscus*, kapok, *Bougainvillea*, cotton, *Acacia*, *Citrus*, and *Ceiba pentandra* are also attacked.

Damage. Branches from 3–8 cm in diameter are completely girdled by the adult beetles with a V-section cut. Only a narrow, central pillar round the pith zone is left, which eventually breaks off. The distal part of the girdled branch is usually much marked with impressions of the adult beetle's jaws.

Pest status. A common, but usually minor pest of cashew in Coast Province, Kenya. However, neglected plantations may be severely damaged.

Life history. Eggs are elongate, about 5 mm long, and are laid singly in transverse slits made in the bark or the girdled branch at points above the girdle.

The larva, which is yellow, mines in the dead wood of the girdled branch. It reaches a length of 45 mm, when fully grown.

Pupation takes place in the dead wood in a chamber prepared by the larva.

The adult is a typical longhorn beetle with a body length of 25–35 mm and with antennae longer than the insect body. The head and thorax are very dark brown. The wing cases are orange with large polygonal black blotches giving them a reticulated appearance.

The total life-cycle takes one year. Adults are on the wing and girdling and egg-laying taking place in the period from May to October.

Distribution. Kenya and Tanzania only. *P. trifasciata* (F.) is found in *Eucalyptus* and *Lannea* in E. Africa.

Control. Once a year in November or December all girdled branches should be collected up and burned. Only the dead or dying part of the branch above the girdle need be collected.

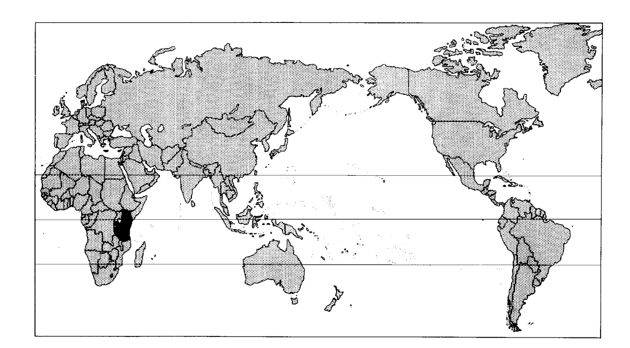
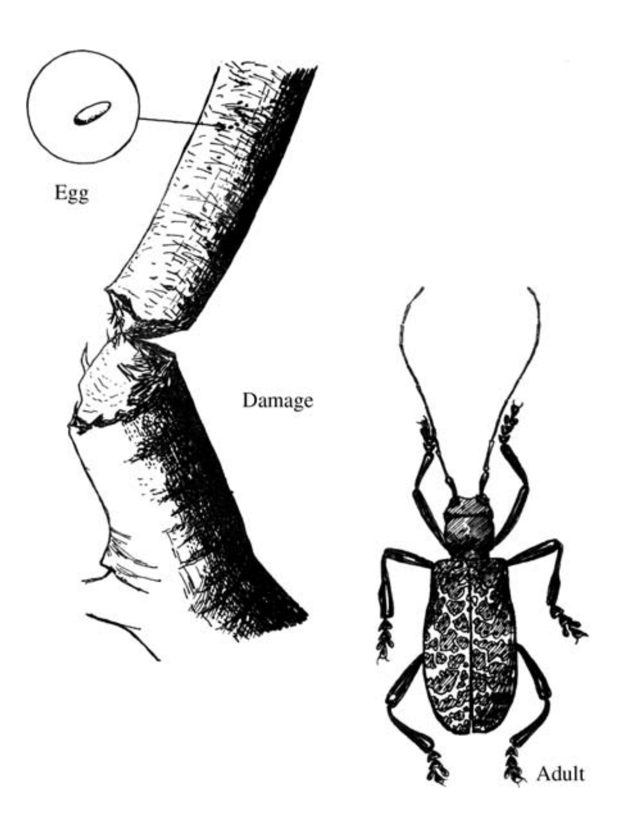


Fig. 9.180. Paranaleptes reticulata (Cashew Stem Girdler); Kenya.



Acanthoscelides obtectus (Say)

Common name. Bean Bruchid
Family. Bruchidae
Hosts (main). Beans of various species.
(alternative). Other pulse crops.
Damage. The infested seeds having mature larvae or pupae inside can be recognized by the presence of a small window; emergence holes are about 2 mm in diameter.
Pest status. A serious pest of beans in many parts of the world, more particularly in tropical countries.
Life history. The infestation by this pest often starts in the field.

The eggs, which are dirty white and pointed, are laid by the female on the ripening pods in the crop.

The tiny larvae are dirty white or pale yellow, with a dark brown head, strong mandibles and rudimentary legs. They bore their way into the seed and feed inside. The presence of mature larvae or pupae can be recognized by the small circular windows on the bean seeds. The life-cycle is completed inside the seed and the adult beetle emerges by pushing the window, which falls off, leaving behind a neat round hole about 2 mm in diameter.

Each female is capable of laying 40–60 eggs. (200 recorded) The life-cycle period is about 4–6 weeks at 28°C and 70% RH.
Distribution. Widely distributed in Europe, Africa, New Zealand, USA, C. and S. America, Canada.
Control. For chemical control the beans should be thoroughly mixed with γ-BHC dust or pyrethrins.

Fumigation should be carried out by approved operators only.

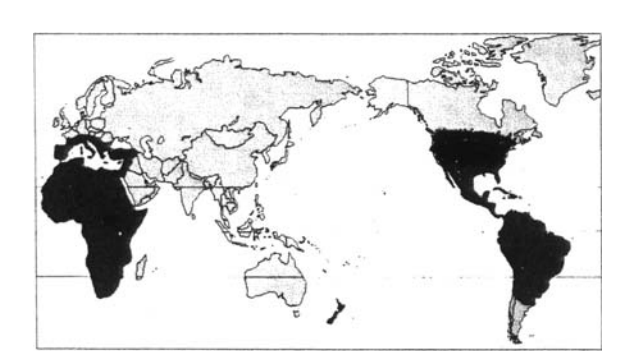
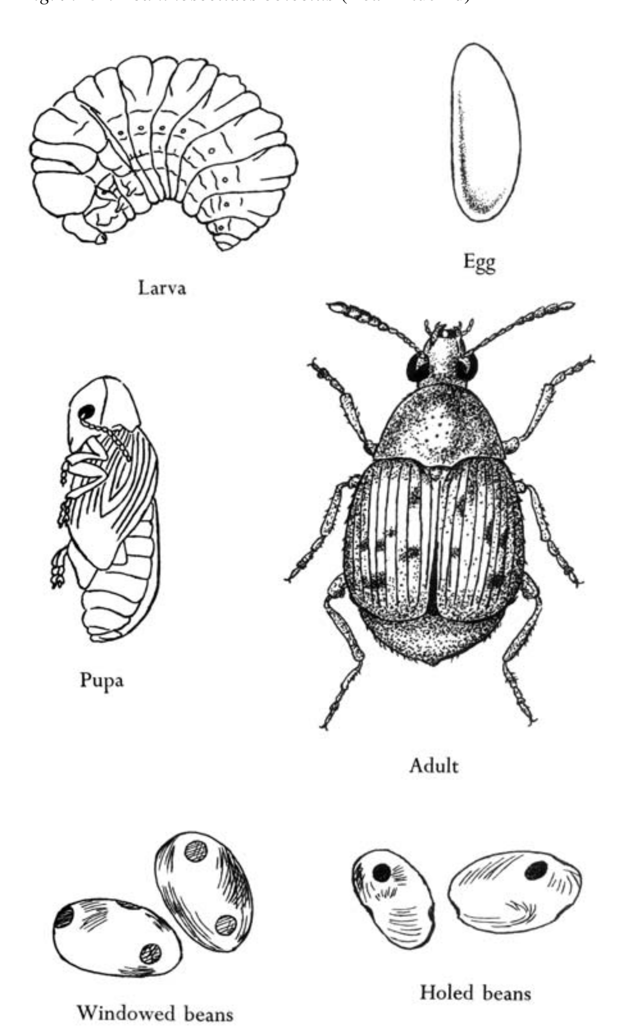


Fig. 9.181. Acanthoscelides obtectus (Bean Btuchid)



Callosobruchus spp.
chinensis (L.)
maculatus (F.)

Common name. Cowpea Bruchids (Oriental/Spotted)
Family. Bruchidae
Hosts (main). Cowpea
(alternative). Soybean, Lentel, chickpea, and other pulses.
Damage. The larvae bore into the pea or bean. Infestations usually originate from farm stores but the adult beetles can fly for up to about half a mile. The infested pods are then harvested and taken into the farm stores where further development takes place. Dried *pods* not attacked, but seeds are.
Pest status. These are important pests of pulse crops in Africa and Asia both on field crops and in stores.
Life history. Eggs are laid, stuck on to the outside of the pods, by the female beetle; each female laying up to 90 eggs. Hatching takes about six days.

The larvae spend their entire life within the pea or bean. On hatching, the larva is scarabaeiform. The larval period is about 20 days.

Pupation takes place in a chamber just under the testa of the seed, this being known as the 'window' stage; pupation takes about seven days to complete.

The adults are small brownish beetles, with characteristically emarginated eyes. Distinctive sexual dimorphism is shown in the antennae.

Adults do not feed - are short-lived (12 days) but fly well.

C. maculatus is a more elongate species with the posterior part of the abdomen not covered by the elytra, and it is more definitely spotted.

The whole life-cycle takes about 4–5 weeks, and about six or seven generations are usual.
Distribution. Cosmopolitan throughout most of the tropics and subtropics. *C. maculatus* is of African origin, and *C. chinensis* is Asian.

Several other species of *Callosobruchus* attack pulse crops in the tropics.
Control. Cultural control can be effective in growing vulnerable crops at least half a mile from farm crop stores which are the primary source of infestation.

Fumigation with methyl bromide in the stores is very effective.

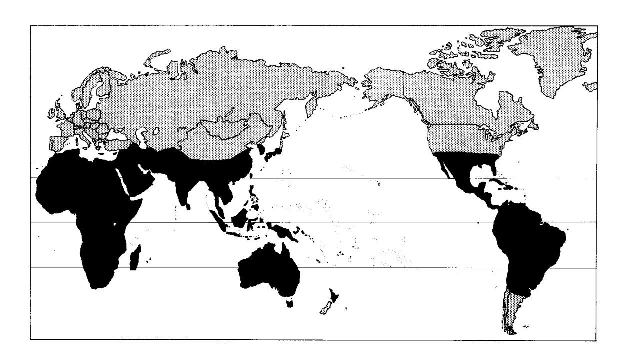
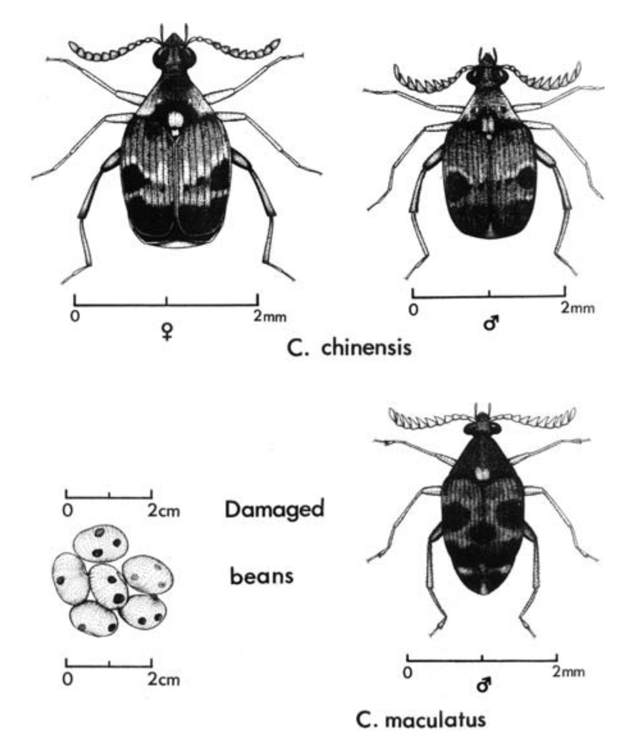


Fig. 9.182. Callosobruchus spp. (Cowpea Bruchids); Kenya.



Caryedon serratus (Ol.)
(= *C. gonagra* (F.))

Common name. Groundnut Borer; Seed Beetle
Family. Bruchidae
Hosts (main). Groundnut and Tamarind packs.
(alternative). Other legumes, including tree legumes.
Damage. The larvae bore into the kernels, and a single larva makes a large hole in the cotyledons; the emerging adult beetle makes a large hole in the pod. Pods are attacked both in the field and in post-harvest storage.
Pest status. A serious primary pest of groundnuts in West Africa.
Life history. Eggs are laid on the outside of the pod, to which they are stuck. On hatching the young larva bores directly through the pod wall from the egg. It then feeds on the cotyledons of the kernel until mature. At this stage there is no sign of damage visible externally. The mature larvae either pupate within the pod or else emerge by boring a large hole and pupate outside in a thin papery cocoon.

The adult is an oval-shaped brown beetle, some 4–7 mm in length, with quite long, serrate antennae, stout hind femora with a row of distal spines and strongly curved hind tibiae. This is one of the Bruchidae that has normal eyes and there are also small blackish spots on the elytra.

The life-cycle takes about 40–42 days under optimum conditions (30–33°C and 70% RH).
Distribution. This pest is common in W. Africa; it also occurs in E. Africa but has not been recorded attacking groundnut there, also found in India, S. USA, and S. America.
Control. Clearly a difficult pest to control with the larvae completely inside the protective pods, but repeated fumigation will destroy infestations.

At present there is no information regarding control of field infestations; however, it is thought that they are seldom at all serious.

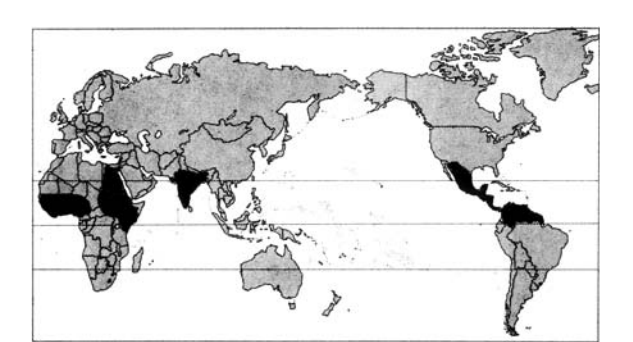
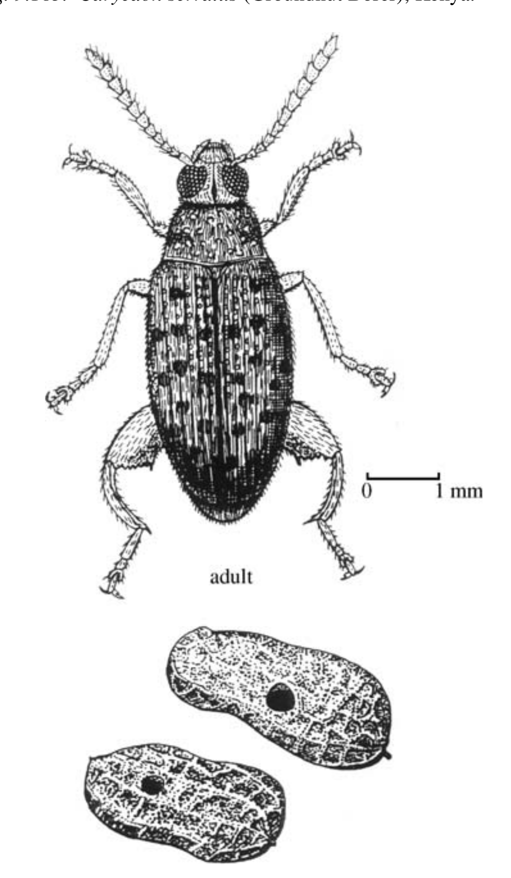


Fig. 9.183. Caryedon serratus (Groundnut Borer); Kenya.



Aspidomorpha spp.

Common name. Tortoise Beetles
Family. Chrysomelidae (Cassidinae)
Hosts (main). Sweet Potato
(alternative). Other Convolvulaceae (e.g. morning glory), coffee, beet, potato, and various flowers.
Damage. Large round holes are eaten in the leaves, by both adults and larvae; occasionally attacks are sufficiently severe to completely skeletonize the leaves.
Pest status. Seldom a serious pest, but one which is very widely distributed and often very common and the damage is quite conspicuous.
Life history. Eggs are laid on the leaves, usually in small (c.20) groups and usually on the underside. Hatching takes about ten days. ♀ may lay c.15 egg masses (300 eggs) in 3–10 month.

The larvae are oval, with a fringe of spines along the margin, and a forked tail carried held up over the back, usually with all the previous cast skins (exuviae) adhering.

The pupa is less spiny than the larva, and is fixed inert to the leaf.

The adult is oval and shield-like, hence the common name of 'tortoise beetle', 6–8 mm long, with broad and flat elytra, often with a beautiful golden iridescence. Life-cycle takes 4–6 weeks.

There are several generations per year in the tropics, but generally only one in temperate countries. ♀ beetle may live for 10 months.
Distribution. Africa, S. China, S.E. Asia, Papua New Guinea, West Irian and the W. Indies.

There are more than 12 species of *Aspidomorpha* in Africa and a dozen in Asia, mostly recorded from sweet potato, and this host also has more than five other genera of Cassidinae in Africa and Asia.
Control. Usually this pest does not warrant control, but diazinon and most contact insecticide sprays would be effective if control should be required.

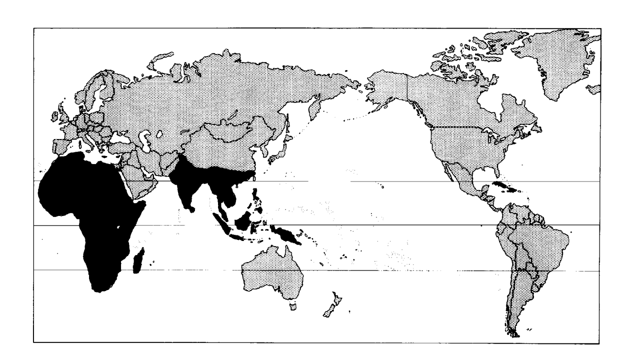
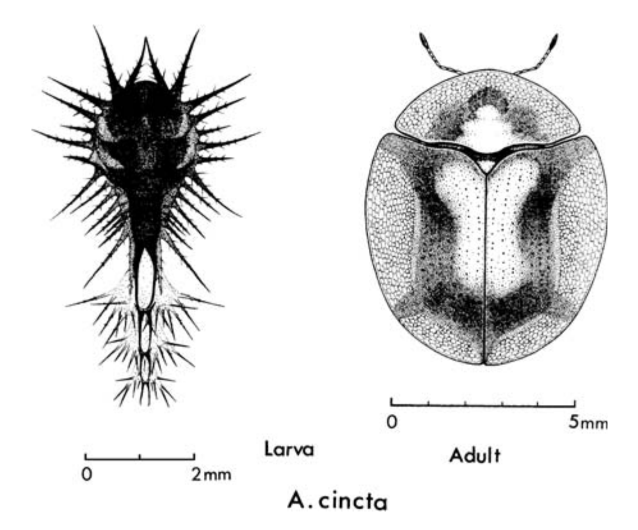


Fig. 9.184. Aspidomorpha sp. (Tortoise Beetle); Kenya.



Oulema oryzae (Kuw.)
(= *Lema oryzae* Kuw.)

Common name. Rice Leaf Beetle
Family. Chrysomelidae (Criocerinae)
Hosts (main). Rice
(alternative). Many species of grass.
Damage. Damage consists of the removal of longitudinal strips of the upper leaf epidermis, giving the leaf a bleached appearance. Excessive damage can result in death of the plant. Damage to floral growth occurs, and can be particularly serious when at the heading stage.
Pest status. A very serious pest of paddy rice in northern Japan, China and Korea, both adults and larvae causing severe leaf damage with regular losses in crop yield of 20–30%.
Life history. Eggs are cylindrical, rounded, 0.8 by 0.3 mm, and they are laid in groups on the upper leaf surface. The oviposition period lasts for about 15 days, and the incubation period 5–11 days.

The larva is squat, with brown nodules on a yellow base, covered with a crust of its own excrement as camouflage, about 4.7 mm long. Larval development takes 13–19 days.

The whitish papery cocoon is usually found on the leaf, but in upland rice fields they may be underground; its size is usually about 4.0–4.5 mm long.

The adult is a small leaf beetle about 4–5 mm long, with shiny black elytra, conspicuously punctate, and a reddish-brown thorax and head. The legs are pale. The adult beetle feeds for only about three months, and spends the rest of the year hibernating in vegetable debris.
Distribution. Japan, China, Ryukyu Isles, Taiwan, Manchuria, Korea, and eastern Siberia.
O. bilineata is a serious pest of tobacco in S. Africa.
O. melanopus is the Cereal Leaf Beetle, widespread in Europe, western and central Asia, and a serious cereal pest in N.E. USA. It is a vector of a virus on cocksfoot grass in Europe (CIE map no. A260).
Control. Applications of DDT, BHC, and phosphamidon have been successful in controlling this pest.

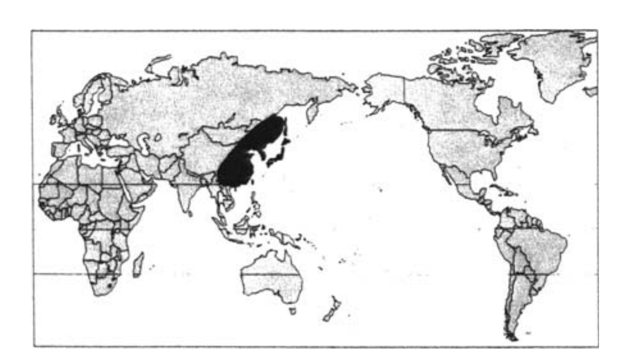
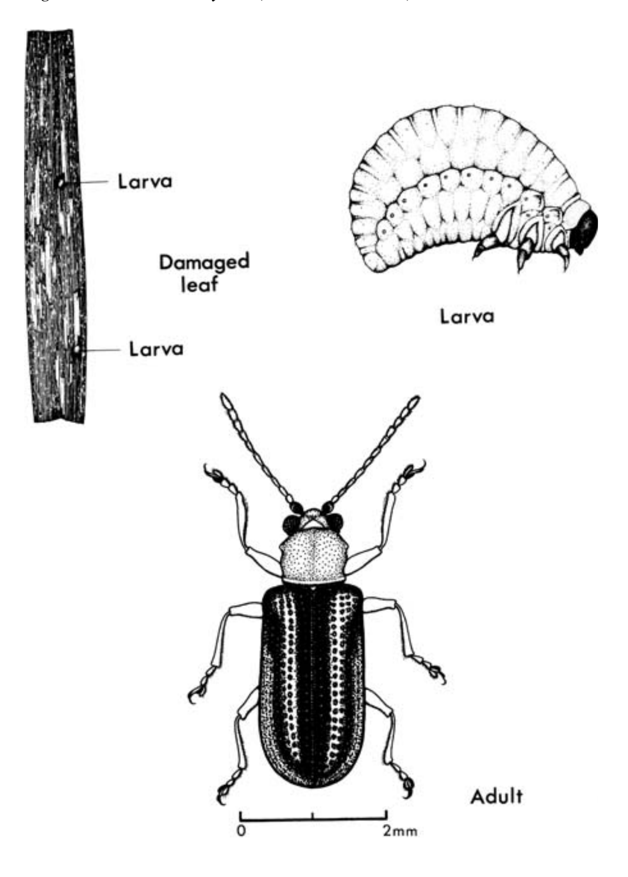


Fig. 9.185. Oulema oryzae (Rice Leaf Beetle); S. China.



Colaspis hypochlora Lefèvre

Common name. Banana Fruit-scarring Beetle
Family. Chrysomelidae (Eumolpinae)
Hosts (main). Bananas
(alternative). A wide range of weeds and grasses.
Damage. The adult beetle feeds on the young unfurled leaves and stems of banana plants, and also eats the skin of young fruit, making scars which spoil the fruit and make it unsalable, and allowing the entry of pathogens.
Pest status. A pest of some past importance in C. and S. American banana-growing areas.
Life history. Eggs are laid in the soil around the banana roots, or in holes gnawed in the roots, singly or in groups of 5–45. Each female can lay several hundred eggs. The incubation period is 6–9 days.

The larvae remain in the soil feeding on the roots of grasses, often to a depth of 25 cm. Larval development takes 20–22 days.

Pupation takes place in the soil, and lasts for 7–10 days.

The adult beetles upon emergence feed on various weeds, as well as the young leaves and fruit of bananas. They are small beetles 5–6 mm long, nocturnal in habit, and they can fly strongly; their normal life span is probably several months. The adult beetles gnaw the banana roots before laying eggs in the soil around the roots.
Distribution. Mexico, Costa Rica, Panama, Nicaragua, Honduras, Guyana, Guatemala, and Colombia.
Control. Clean cultivation, mainly being the removal of grass weeds from plantations, will help to reduce populations often enough to avoid the use of insecticides.

Should chemical control really be necessary then endrin, aldrin, and dieldrin have been found to be effective.

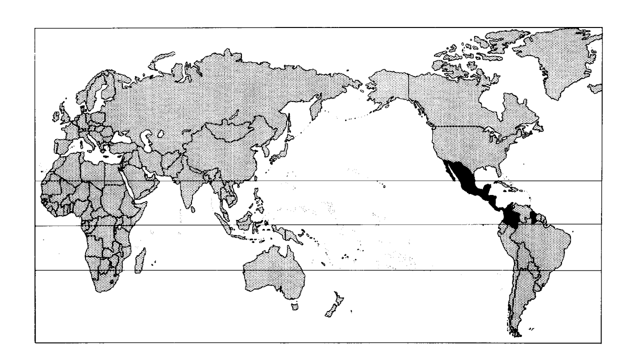
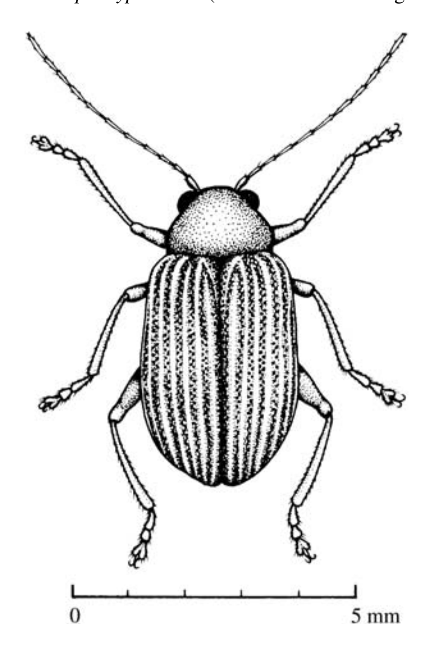


Fig. 9.186. Colaspis hypochlora (Banana Fruit-Scarring Beetle).



Leptinotarsa decemlineata (Say)

Common name. Colorado Beetle
Family. Chrysomelidae (Chrysomelinae)
Hosts (main). Potato
(alternative). Eggplant, tomato, and various other (only some) cultivated and wild Solanaceae.
Damage. Both adults and larvae feed on the leaves, and a heavy infestation results in complete defoliation and a severely reduced yield; a 50% loss is usual. A characteristic black and messy excrement is left on the leaves.
Pest status. A very serious pest of potato, and other solanaceous crops, in Europe and the USA. In the UK, in 1933, was passed the Colorado Beetle Order as a legislative measure of control against accidental introductions.
Life history. Eggs are orange-yellow, laid in batches, usually underneath the leaves. Each female lays 500–800 eggs throughout the summer period (up to 2500 eggs are recorded); hatching requires 4–6 days.

Larvae are brown initially, later becoming bright pink with two rows of black spots laterally; they generally stay on the same plant, and eat the foliage. Larval development takes 20–4 days. Fully grown larvae (about 12 mm long) burrow into the soil to pupate inside an earthen cell; pupation takes about 5–16 days; then the first-generation adults emerge, usually in July. Second-generation adults remain in the soil and overwinter in hibernation, at a depth of 10–25 cm.

The adults are rounded beetles with alternating black and yellow stripes along the elytra; 10–12 mm in length. The spring dispersal flights are usually 2–5 km.
Distribution. Endemic to semi-desert regions in the western USA, on wild Solanaceae, it spread and became more numerous with widespread potato cultivation. Now recorded from throughout the USA, southern Canada, Mexico and Costa Rica, and in 1922 became established in France; now spread throughout most of Europe, but to date kept out of the UK (CIE map nos. A.6 and 139).
Control. Control is best effected by low-volume sprays of azinphos-methyl, carbaryl, DDT, or phosphamidon on the foliage of the plants, in addition to injecting the soil with D-D or metham-sodium to kill pupae and resting adults.

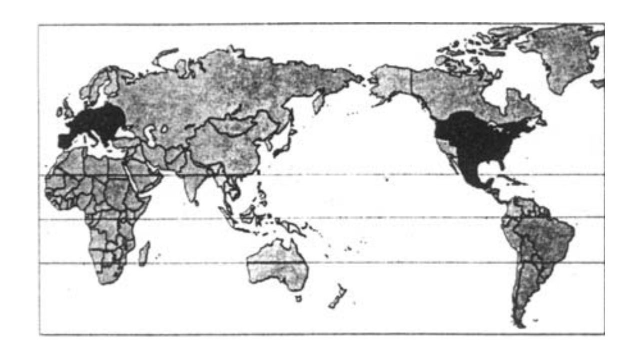
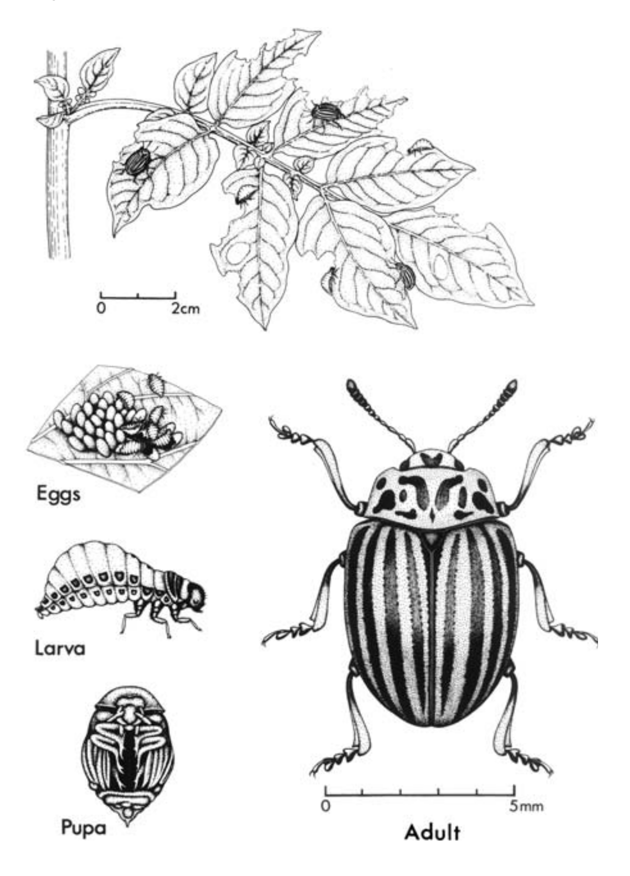


Fig. 9.187. Leptinotarsa decemlineata (Colorado Beetle); England.



Diabrotica spp.

(*D. balteata* LeConte)
(*D. longicornis* S. & L.)
(*D. undecimpunctata* Mann.)

Common name. Banded Cucumber Beetle
Northern Corn Rootworm
Spotted Cucumber Beetle.
Family. Chrysomelidae (Galerucinae)
Hosts (main). Cucurbits, maize.
(alternative). Sunflower, tobacco, groundnut, and many other crops.
Damage. The soil-dwelling larvae eat the roots of maize (corn), hence their names of 'rootworms' and they burrow into the stem often killing the seedling; the adults eat foliage, and the silks of maize, and several species show preference for flowers and foliage of Cucurbitaceae.
Pest status. Collectively this group is important as they are quite serious pests of both maize and cucurbits. Some species transmit Cucumber Mosaic Virus, and bacterial wilts of both maize and cucumbers.
Life history. Eggs are laid in the soil; they may overwinter in northern locations.

The larvae are small, wrinkled, yellowish-white with a brown head capsule. After a total developmental time of about 30 days they grow to 10–18 mm in length. Pupation takes place in an earthen cell in the soil.

The adult beetles are quite small, only 5–6 mm in length, but distinctively marked with spots and bands across or along the elytra; basic body coloration is pale greenish-yellow.

The life-cycle takes some 50 days under warm conditions; in the southern States there may be as many as six generations per year (*D. balteata*), but in Canada the other two species may be univoltine.

D. longicornis appears to be restricted to maize, whereas the other species tend to be more general feeders. It might, in point of fact, be more satisfactory to consider each species separately as there are some fundamental differences in their biology and distributions within the New World.
Distribution. These are essentially New World species and recorded distribution extends from Canada, throughout the USA, C. and S. America.

Other important species include:
Diabrotica v. virginifera LeConte – Western Corn Rootworm.
Diabrotica virginifera zeae K. & S. – Mexican Corn Rootworm.

A closely related group of cucumber pests are placed in the genus *Acalymma*, specifically *Acalymma vittata* (F.) – Striped Cucumber Beetle; Canada and USA, and *A. trivittatum* (Mann.) – Western Striped Cucumber Beetle of the USA. Both species closely resemble *Diabrotica* spp. but are distinctively striped longitudinally.
Control. In areas at risk, the avoidance of winter crops such as alfalfa, which encourages the pests in the spring, will reduce populations.

Most species are now showing resistance to the previously used organochlorines and if control is really required then soil application of granules of diazinon, phorate or parathion are generally effective.

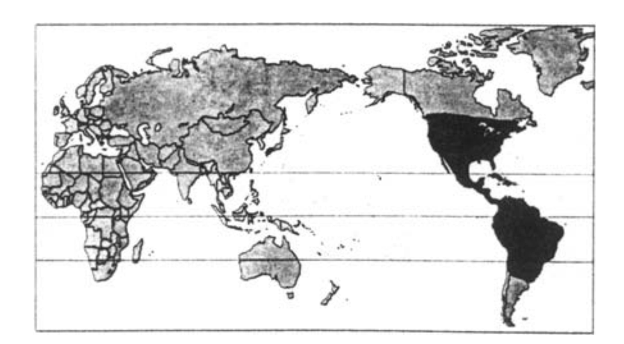
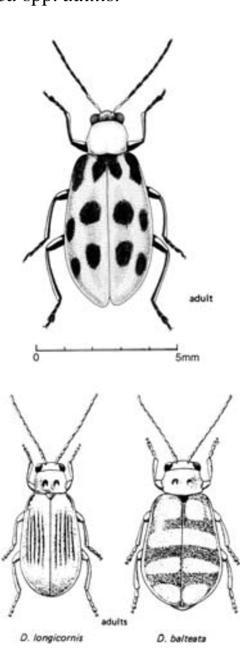
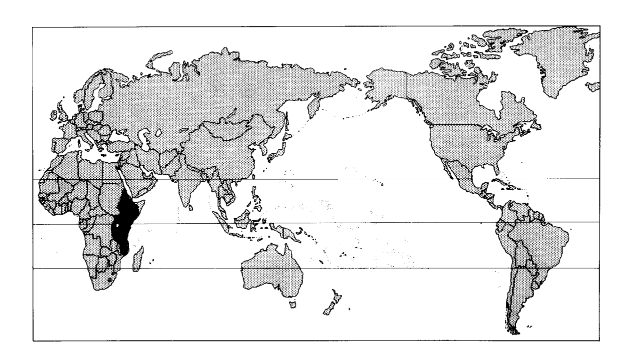


Fig 9.188. Diabrotica spp. *adults.*



Megalognatha rufiventris Baly

Common name. Maize Tassel Beetle
Family. Chrysomelidae (Galerucinae)
Hosts (main). Maize
(alternative). Many other plants
Damage. On maize this pest congregates on the cobs and they devour the silks, and occasionally they penetrate the sheaths and destroy the seed embryos. Damage is done solely by the adult beetles.
Pest status. This pest periodically occurs in large numbers in E. Africa and causes severe damage to many crops when this happens.

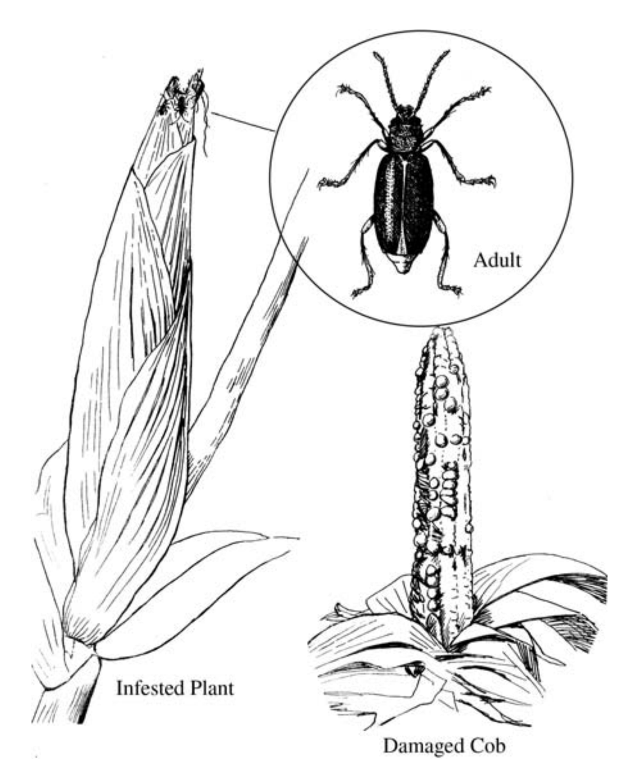


Life history. Details of the life history of this beetle are not known.

The adult is a small black beetle with a pale reddish-brown abdomen, the tip of which protudes below the end of the elytra.
Distribution. E. Africa only.

In E. Africa 13 other species of *Megalognatha* are recorded, feeding on Acacia, avocado, mango, maize, eucalyptus, coffee, cotton, plum and peach (mostly leaves).
Control. Control is usually achieved easily by dusting the crop with contact insecticides.

Fig. 9.189. Megalognatha rufiventris (Maize Tassel Beetle); Kenya.



Monolepta spp.

Common name. White-spotted Leaf Beetles, etc.
Family. Chrysomelidae (Galerucinae)
Hosts. This is a regular minor pest on a number of different crops, including Cucurbitaceae and grapevine; closely related species in Africa and Australia feed on maize, *Citrus*, various stone fruits, cotton, groundnut, mango and cashew.
Damage. The adult beetles eat holes in the leaf lamina.
Pest status. A common and widespread pest, especially at generic level, on many different hosts, but usually only important as part of a pest complex.
Life history. No details are known for this pest.

The adult is a small, dark beetle, about 2–3 mm in body length, with long antennae and two pairs of large pale spots on the elytra.

The other recorded pest species are similarly patterned, but *M. australis* (Red-shouldered Leaf Beetle) is basically yellow with red spots at the elytra bases.
Distribution. M. signata is found from India, through S.E. Asia, to S. China and the Philippines.

M. australis (Jac.) is found in Australia; *M. dahlmanni* (Jac.) and *M. duplicata* (Sahlb.) in tropical Africa, and M. punctipes in Ethiopia.
Control. Usually not required.

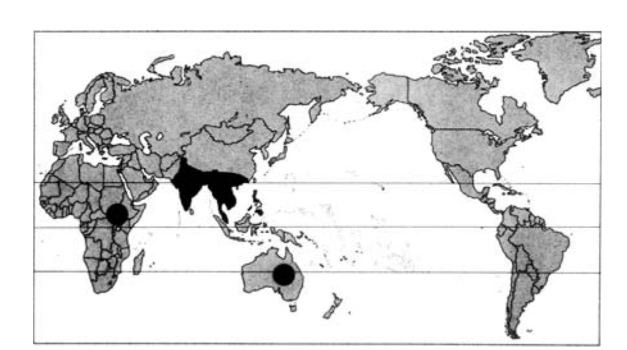
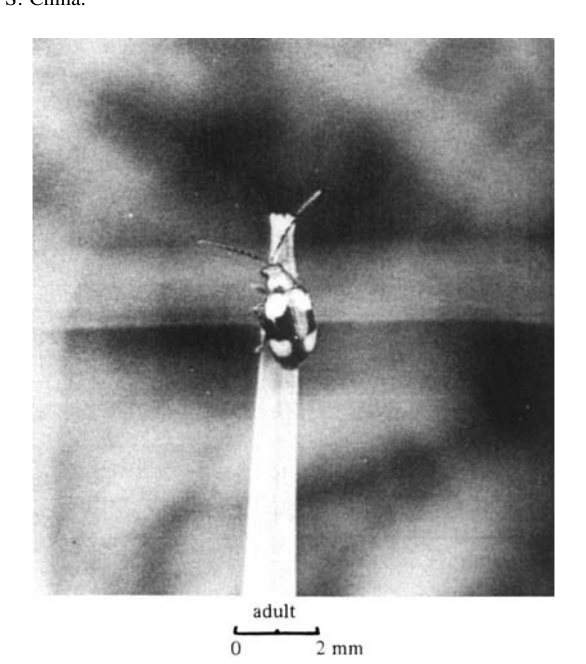
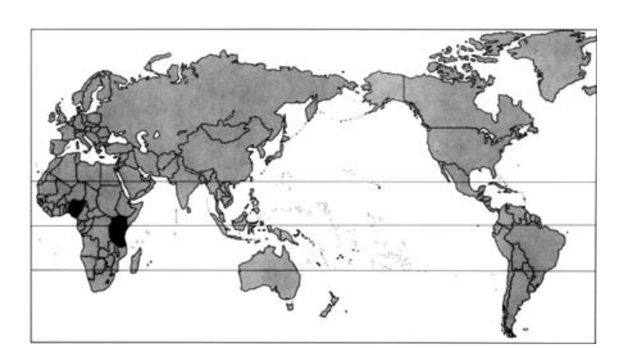


Fig. 9.190. Monolepta signata (White-spotted Leaf Beetle); S. China.



Ootheca mutabilis (Sahlb.)

Common name. Brown Leaf Beetle
Family. Chrysomelidae (Galerucinae)
Hosts (main). Groundnut, sesame, beans, cowpea, and other pulses.
(alternative). Coffee, cocoa, and cotton.
Damage. Young leaves are attacked and eaten by the adult beetles. Damage is typical of that done by leaf-beetles. It is reported as being a vector of Cowpea Yellow Mosaic virus, and in Nigeria it sometimes occurs in considerable swarms, when damage can be extensive.
Pest status. Not a serious pest usually, but of quite frequent occurrence on many leguminous crops.



Life history. The biology of this pest is not known in detail.

Eggs are laid in the soil.

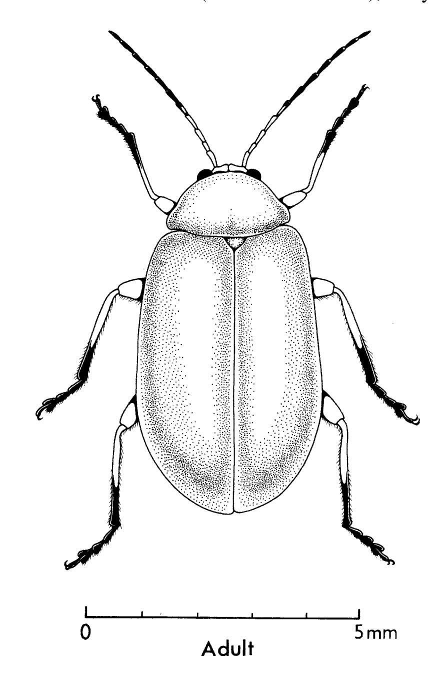
The larvae feed on the roots of various plants.

Pupation takes place in the soil, during the dry season.

The adults emerge with the early rains, and attack the seedling plants. The adult is an oval, shiny, convex-shaped beetle, about 6–8 mm long, yellowish-red or brownish, with a black head and legs.
Distribution. Nigeria, and E. Africa.

Several other closely related species are found mostly on leguminous crops.
Control. Control measures are not usually advocated.

Fig. 9.191. Ootheca mutabilis (Brown Leaf Beetle); Kenya.



Phyllotreta spp.

Common name. Cabbage Flea Beetles
Family. Chrysomelidae (Halticinae)
Hosts (main). Brassicas and Cruciferae.
(alternative). Cotton, cereals.
Damage. The adults feed on the cotyledons and leaves of young plants, and the feeding produces a shot-hole effect. Occasionally seedlings may be completely destroyed. The larvae live in the soil and feed upon the roots of the host plants.
Pest status. These are usually only minor pests but they are very widespread and common.
Life history. Eggs are laid in the soil by the host plant.

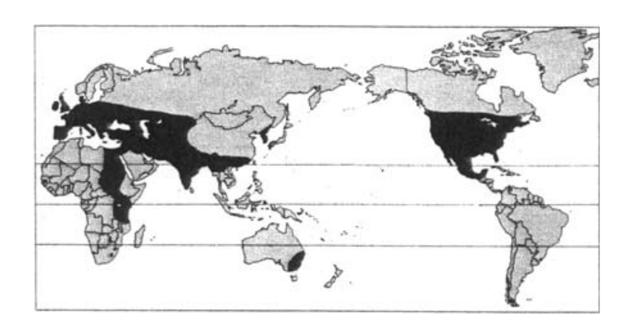
The larvae of most species of *Phyllotreta* feed upon the roots, and do little damage.

Pupation takes place in the soil.

The adults vary in colour from shiny black, to black with a green sheen, to black with yellow stripes on the elytra. All species have very stout femora with which they jump in a flea-like manner. The adults hibernate in the soil litter or in hedgerows.

In Europe there are two or three generations per year. The main damage is done in the spring by the adults which emerge from hibernation and resume feeding at the time when many crop seedlings are available.

Distribution. The genus *Phyllotreta* is very widely distributed in most parts of the world; 12 + species of *Phyllotreta* are pests on cruciferous crops; one on cereals, and one on cotton.

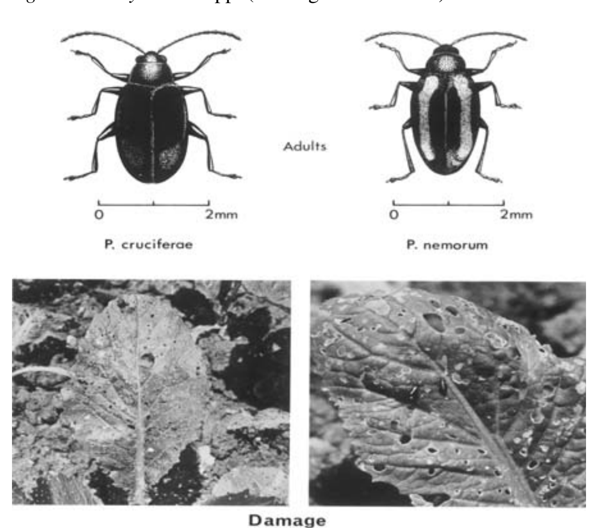


Four of the most common species are: *P. cruciferae* (Goeze) – in Europe, Asia, Middle East, Egypt, USSR, and N. America; *P. nemorum* (L.) – Europe, Asia, USSR, Korea and S.E. Australia; *P. cheiranthei* Weise – Egypt, E. Africa, Sudan and Sri Lanka; and *P. striolata* – S. China.

Twenty or more genera of flea beetles are recorded from a wide range of crops throughout the tropical parts of the world.

Control. If control is required, a seed dressing of BHC, or treatment with DDT, BHC or derris dust, fenitrothion is generally effective.

Fig. 9.192. Phyllotreta spp. (Cabbage Flea Beetles)



Damaged
Leaf

Flea beetles (Coleoptera; Chrysomelidae; Halticinae)

This group contains a very large number of mostly tiny dark leaf beetles all with similar oval, rounded bodies, longish antennae, and stout hind femora with which they make their flea-like prodigious leaps. They feed on the foliage of a wide range of plants, from grasses and herbs, to shrubs and trees. Typical feeding damage consists of small shot-holes in the leaf lamina (see illustrations on pages 85 and 309) and seedling stems may be gnawed. Generally the adults overwinter by hibernating in leaf litter and plant debris, thus infestations may be very heavy in the early spring and seedling damage may be very serious. Entire crops may be destroyed whilst still at the cotyledon stage.

The larvae are elongate and cylindrical in shape, like tiny wireworms, and are usually to be found in the soil where they feed on plant roots and generally are of little consequence economically. However there is some diversity of larval biology; the larvae of *Prodagricomela nigricollis* mine leaves of *Citrus* in China (Hill, 1983; page 473) in a most conspicuous manner; *Phyllotreta nemorum* larvae mine the leaves and stems of *Brassica* spp., making small blister mines that later dry up and are generally quite inconspicuous. Larvae of *Epitrix cucumeris* and *E. tuberis* make tunnel mines on the surface of potato tubers in Canada and the USA. *Psylliodes chrysocephala* has larvae that make galls in the stems of overwintering brassicas. In some species of *Altica* the larvae live on the leaf surface alongside the adults (as do many other Chrysomelidae) where they hole the lamina of the leaf and cover the surface with a messy black excrement (Hill, 1982; page 130).

Important pest species of flea beetles

In addition to the species included in this chapter, there are many other species of economic significance throughout the world. Field identification of flea beetles is often very difficult, even in the cases where the adults are brightly coloured or patterned, because of the very large number of species that occur in most of the genera. Groups of some economic importance include:

Altica spp. (= *Haltica*) – a large, worldwide genus of small bluish beetles, with several pest species in Asia, at least five pest species in the USA, and seven species mostly from crop plants in the UK.
Aphthona euphorbiae (Schrank) – (Large Flax Flea Beetle) recorded only from flax; throughout Europe and the UK.
Aphthona spp. –many are recorded from wild herbaceous plants in Europe, but some species prefer tree hosts in eastern Europe and Asia; eight species recorded from the UK.
Argopistes spp. – (Citrus Flea Beetles) from China and Japan; also one species recorded from privet in China.
Disonycha spp. – on spinach and other vegetables; in Canada and the USA.
Epitrix cucumeris (Harris) – (Potato Flea Beetle) on potato, tobacco, eggplant, cucurbits, and other crops; Canada and the USA.
E. fuscula Crotch – (Eggplant Flea Beetle) on Solanaceae; USA.
E. hirtipennis (Melsh.)–(Tobacco Flea Beetle) on tobacco and tomato; Canada and USA.
E. subcrinata LeConte – (Western Potato Flea Beetle) mostly on potato; Canada and USA.
E. tuberis Gentner – (Tuber Flea Beetle) polyphagous on potato and many vegetable and other crops; Canada and USA.
Epitrix spp. – other pest species are known in N. America, mostly preferring Solanaceae as hosts; in Europe several-species feed on wild Solanaceae.
Longitarsus parvulus (Payk.) – (Flax Flea Beetle) apparently only recorded from flax; found throughout Europe; in the UK a total of 41 species of *Longitarsus* are recorded from wild herbaceous hosts in several different families (Compositae, Labiatae, Leguminosae, etc.).
Prodagricomela nigricollis Chen – (Citrus Flea Beetle/ Leaf Miner) only recorded to date from *Citrus* spp. in S. China.
Systena blanda Melsh. – (Pale Striped Flea Beetle) polyphagous on many crops; Canada and USA.
S. elongata (F.) – (Elongate Flea Beetle) USA.
S. frontalis (F.) – (Red-headed Flea Beetle) on clovers and many other crops; Canada.
Systena spp. – at least three other species are polyphagous crop pests throughout Canada and USA.
Phyllotreta spp. (Cruciferous Flea Beetles) 12+ species are pests on cruciferous crops throughout the world.
P. robusta Lec. – (Garden Flea Beetle) crucifers and some garden plants; Canada.
P. striolata (F.)–(Striped Flea Beetle) on crucifers; China, Japan, Canada and USA.
P. undulata Kuts. – (Small Striped Flea Beetle) on crucifers; Europe.
P. vittula Redt. – (Barley Flea Beetle) attacks barley, also other temperate cereals, as well as Cruciferae; Europe.

Most temperate countries have a large number of *Phyllotreta* species on their faunal checklists; the UK is fairly typical and has 14 species, the majority of which are agricultural pests.

Control of flea beetles

Because of the adults hibernating over winter, it is mostly the seedling stage of the crop that has to be protected; damage to trees and established shrubs and herbs is seldom serious as compensatory growth will maintain an adequate leaf area index.

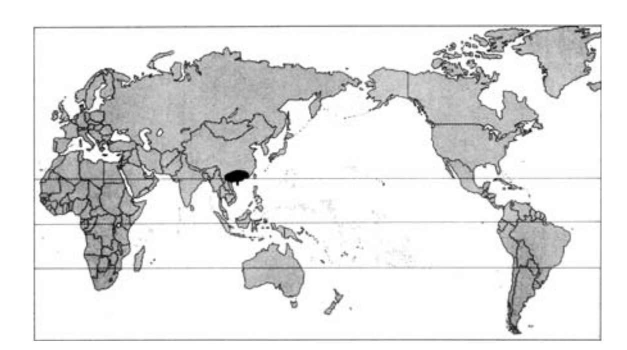
Cultural methods. Use of good seedbeds (moist, fine tilth, fertilized, etc.) will help young plants to grow quickly through the susceptible seedling stage.

Chemical methods. Insecticides may be used in several different ways in order to combat flea beetles, as follows:

(1) Seed treatment – dressings, etc., of HCH; followed, if required, by later treatment of the growing crop (sprays of HCH, carbaryl, diazinon).
(2) Dusting or spraying of the crop after infestation is evident, with DDT, HCH, carbaryl or diazinon.
(3) Soil application of granules at sowing – primarily for control of other soil-dwelling pests (e.g. Cabbage Root Fly; beet seedling pests); carbofuran is recommended for this purpose.

Prodagricomela nigricollis Chen

Common name. Citrus Flea Beetle; Citrus Leaf-miner
Family. Chrysomelidae (Halticinae)
Hosts (main). *Citrus* spp.
(alternative). Some other species of Rutaceae.
Damage. This is a most unusual member of the Halticinae in that both adult and larvae damage the host plant. The adult eats windows in the leaves, from the underneath, and in heavy attacks can skeletonize the whole leaf; the larvae mines in the leaf making a broad tunnel mine with a conspicuous line of faecal pellets along the centre. Heavy attacks result in considerable leaf loss.
Pest status. A common pest of *Citrus* in S. China, but not classed as serious; more of academic interest because of the unusual life-cycle.

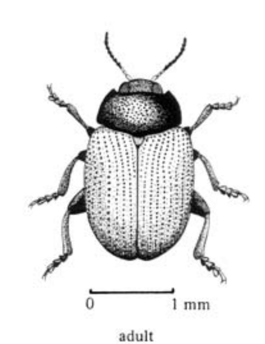


Pupation takes place in the soil or leaf litter under the infested tree. Adults emerge in June in S. China whereupon they aestivate and hibernate underground until the following March/April.

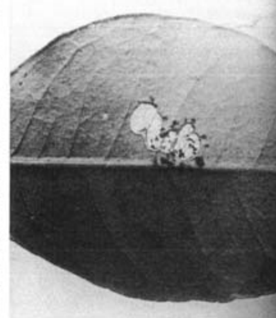
There is only the one generation per year.
Distribution. To date, only recorded from S. China.
Life history. Egg-laying starts in early April, lasting for about a month, and by the end of April the first larval mines are to be found. The larva is orange-yellow in colour with an elongate body and reduced legs, and when full grown is about 5 mm in length.
Control. In China the hand-picking of infested leaves to control the eggs and larvae has been practised, together with clean cultivation to control the pupae. In Hong Kong chemical control is practised against this pest.

Fig. 9.193. Prodagricomela nigricollis (Citrus Flea Beetle); S. China.









Dicladispa armigera (O1.)

Common name. Paddy Hispid
Family. Chrysomelidae (Hispinae)
Hosts (main). Rice
(alternative). Various grass species.
Damage. Young rice plants are attacked by both adults and larvae; the adults feed on the green part of the leaf, leaving only the epidermal membranes – the feeding damage showing as characteristic white streaks along the long axis of the leaf. The larvae mine in the leaves between the epidermal membranes, producing elongate white patches. Damage starts from the leaf tip and extends back towards the leaf base; attacked leaves wither and die. Virus vector
Pest status. A serious pest of rice, particularly in Bangladesh, but also important in other parts of S.E. Asia.
Life history. Eggs are laid singly, embedded in the lower epidermis of the rice leaves, near the leaf tip. Hatching takes 4–5 days. Each female lays about 55 eggs.

The larvae are minute, pale yellow, depressed, and about 2.5 mm long. Immediately after hatching the larvae burrow into the leaf, where they feed for 7–12 days before pupation.

The pupae are brown, depressed, exarate, and lie in the larval tunnel. Pupation takes 4–5 days.

The adults are small, shiny, blue-black beetles, about 5.5 mm long with spines on the thorax and elytra.
Distribution. Pakistan, India, Bangladesh, Sri Lanka, Burma, Malaysia, Sumatra, Java, Cambodia, Thailand, Laos, Vietnam, S. China, and West Irian (CIE map no. A228).

Two other species of *Dicladispa* are found on rice in Madagascar and in Eastern Africa. Several other species occur on other hosts in Indonesia.
Control. Removal of grass weeds from around the paddy fields will lower the pest population, as also will the cutting off of the tips of the rice leaves at the start of an infestation.

Pesticides which have been effective are dieldrin, endrin, phosphamidon, demeton-*S*-methyl, BHC, fenthion, fenitrothie DDT, and diazinon, as foliar sprays, and carbofuran, thiodemeton, phorate and disulfoton as granules.

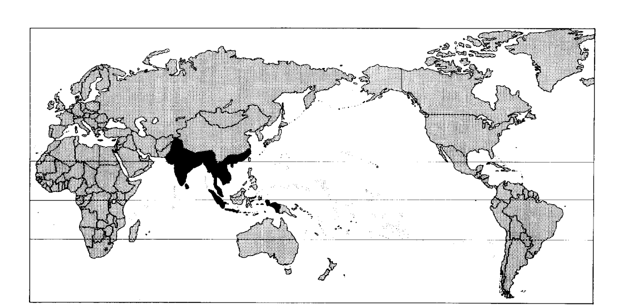
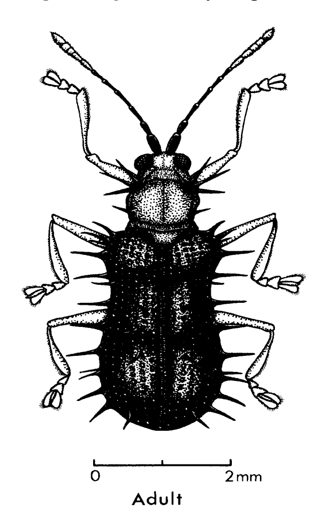
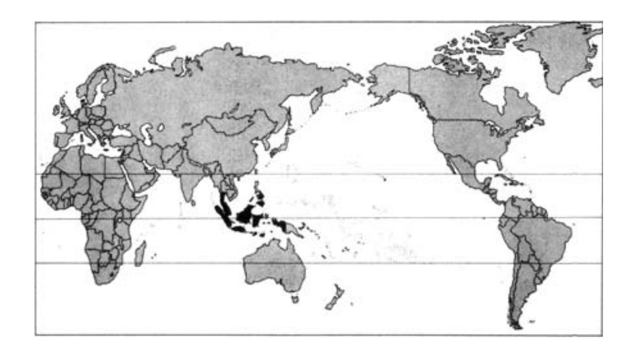


Fig. 9.193. Dicladispa armigera (Paddy Hispid).



Plesispa reichei Chap.

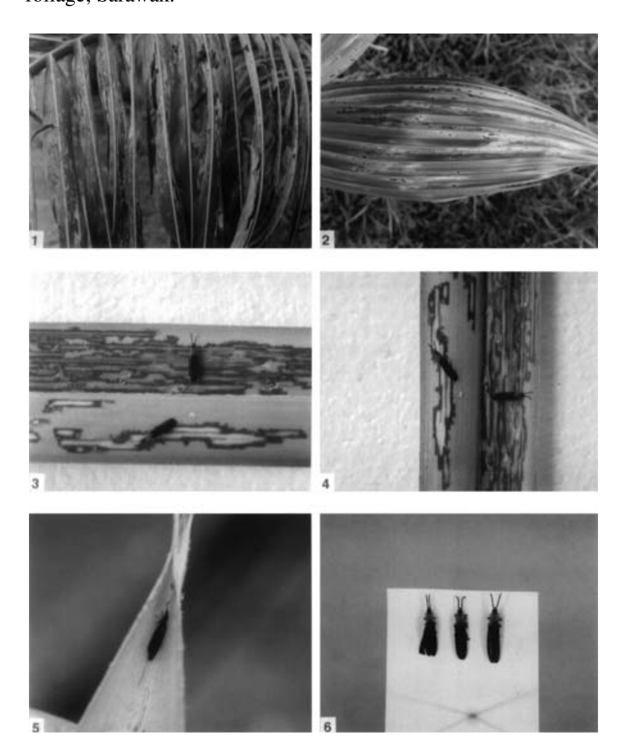
Common Name Coconut Palm Hispid
Family Chrysomelidae (Hispinae)
Hosts Coconut Palm (mostly young plants 3–4 years old. *Oreodoxa regia* recorded in Malaysia.
Damage Characteristically adults and larvae feed on young unopened leaflets and make feeding scars parallel to the main vein, as the leaflets open the damaged tissue dies and the leaflets are esily shredded by wind action. Seedling growth is impaired and the plants may be killed. On mature palms the beetles attack the tips of recenyly unfolded leaflets - the leaf tip folds over and makes a small chamber where the eggs are laid and the larvae develop.
Pest Status Of regular occurrence on Coconut Palms in S.E. Asia but only occasionally is serious damage done. In most cases the pest is kept in check by its natural enemies.



Life History The beetles have an orange-yellow head and pronotum and black elytra, and are 7–8 mm long - the female is slightly larger. Eggs are laid singly within the folded learlet tip - each female can live for 6–8 months and lays 50–100 eggs. Incubation takes about 10 days. Larval development takes 30–40 days and pupal 6–11 days. The entire life cycle takes 40–64 days.
Distribution Indonesia, Malaysia, Philippines and Samoa.
Control Damage is seldom serious enough to warrant the use of insecticides, most populations are kept in check by their natural enemies - the eggs and larvae are attacked by a wide range of parasitic Chalcidoidea.

P. nipae is found on wild Nipah Palms in Malaysia and Java. Several very similar species are found on Coconut and other Palmae in S.E. Asia, and these include *Brontispa* species and *Wallaceana* species.

Fig. 9.194. Plesispa reichei (Coconut Palm Hispid) on coconut foliage; Sarawak.



Promecotheca cumingii Baly

Common Name (Coconut) Palm Leafminer
Family Chrysomelidae (Hispinae)
Hosts (main). Coconut Palm and Oil Palm
(alternative). Other Palmae including *Areca*, *Nipa* and *Metroxylon*.
Damage Young larvae mine in the leaflets of mature leaves and make tunnels about 10 cm long and 1 cm wide. Adults make long narrow feeding scars on the leaflets. The overall result is that the foliage withers and appears scorched; the palm seldom dies but the crop yield is reduced for usually a year and a half.
Pest Status Occasional population 'explosions' occur and damage is extensive and widespread - this is thought to occur when the natural enemies are reduced in numbers, and fruit shedding can be common and many trees may die. Often the leaf damage is associated with fungal attack (*Pestaloptiopsis*).
Life History Eggs are laid singly in small cavities on the undersides of the leaflets, and incubation takes 13–24 days; each female lays about 120 eggs over 8–15 weeks. The larvae mine the leaflets making long blotch mines. Pupation takes place at the end of the mine. Larval development takes about 32 days, and pupal 7 days. The adult beetles are about 7–9 mm long, and reddish-brown in colour, and feet and antennae black. They are slow moving and do not fly far. Usually there are several overlapping generations per year.
Distribution *P. cumingii* and the closely realted *P. soror* are found in Java, Malaysia, Borneo, Sulawesi and the Philippines. Some other species occur throughout Indonesia, New Guinea, N. Australia and the S. Pacific, where their hosts also include Zingiberaceae and *Flagellaria. P. papuana* is probably the best known species.
Control Insecticidal treatment has generally been unsuccessful and usually kills off many of the valuable natural parasites. Plantation hygiene including destruction of infested fronds can have a beneficial effect. The many natural parasites generally keep the pest populations down. Several important parasites have been reared and released locally in previous years, some with considerable success.

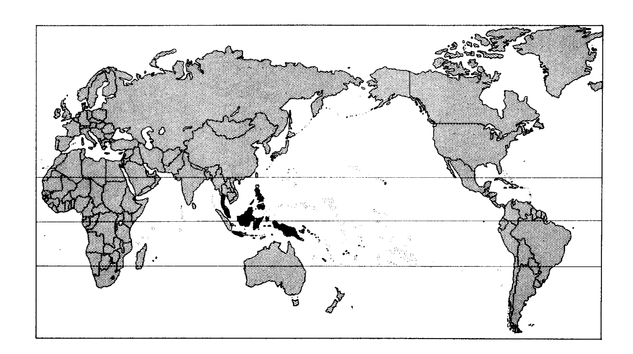


Fig. 9.195. Promecotheca cumingii (Palm Leaf Miners); Sarawak.



Trichispa sericea (Guérin)

Common name. Rice Hispid
Family. Chrysomelidae (Hispinae)
Hosts (main). Rice
(alternative). None recorded, but probably species of wild grasses.
Damage. Attacked plants have irregular pale brown patches and narrow whitish streaks on the leaves; the pale brown patches are the larval mines, and the whitish streaks are the feeding scars produced by the adults.
Pest status. An important pest in rice nurseries, only sporadically serious on transplanted rice.
Life history. Eggs are laid singly in slits in the leaf made by the adult beetle, the wound being covered by a spot of excreta. Hatching takes place after 3–4 days.

The larva is a slender, yellowish grub which when fully grown is about 6 mm long. It feeds inside the leaf, the mine being visible externally as a pale brown blotch. The larval period lasts about ten days.

Pupation takes place within the mine, the pupal stage lasting about six days.

The adult is a dark grey beetle covered with upright spines. It is about 3–4 mm long. Adult females live for about two weeks and may lay more than 100 eggs during this period. Adults feed externally on the leaves, the damage being visible as narrow whitish streaks parallel to the veins.
Distribution. Only recorded from Africa; Angola, Senegal, Mali, Cameroons, Nigeria, Togo, Ivory Coast, Zaïre, Swaziland, Sudan, Ethiopia, Burundi, Rwanda, Uganda, Kenya, Tanzania including Zanzibar, S. Africa, and Madagascar (CIE map no. A257).
Control. Sprays of BHC or DDT were recommended in either high- or low-volume according to the spraying machinery available; BHC is to be preferred as it kills both larvae and adults.

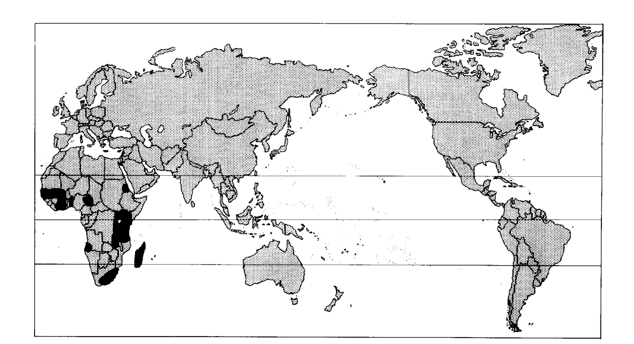
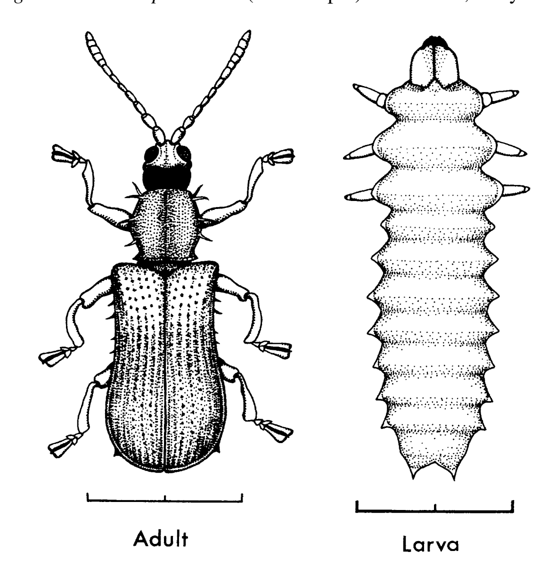


Fig. 9.196. Trichispa sericea (Rice Hispid) Adult larva; Kenya.



Cylas formicarius (F.)

Common name. Sweet Potato Weevil
Family. Apionidae (Curculionoidea)
Hosts (main). Sweet potato
(alternative). Some other species of *Ipomoea* (not all).
Damage. The larvae bore into the tubers and stems, where they feed, and eventually pupate. The tunnel systems are usually infected with fungi and bacteria causing extensive rotting of the tubers. Adults are also found in the tunnel systems and on the leaves of the plant, on which they feed; 112 adults recorded from a single tuber.
Pest status. A serious pest of sweet potato causing extensive damage to field crops throughout the tropical parts of the world; the damage to the tubers continues during storage, which makes this an even more important pest.
Life history. Eggs are laid singly in hollows in the stem, or else inserted directly into the tubers. Hatching requires about one week.

The larvae are white, curved, and apodous, and they tunnel inside both stems and tubers, for about 2–4 weeks, making tunnels some 3 mm in diameter. Pupation takes place within the larval tunnels and requires about one week.

The adult is a small, black weevil with brown thorax and legs, about 6–8 mm in length. Sexual dimorphism is apparent in the antennae, the males having a long antennal club. Adults are long-lived, active, and fly quite readily.

The life-cycle takes some 6–7 weeks usually; and there are several generations each year.
Distribution. Recorded as common from tropical Africa, India, S.E. Asia, Australasia, Hawaii, S. USA, W. Indies and S. America (CIE map no. A278).
Control. See under *Cylas puncticollis*.

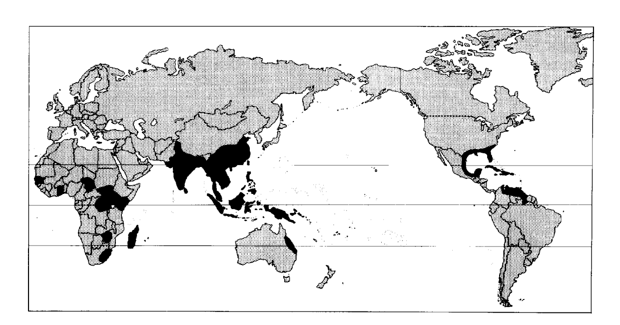
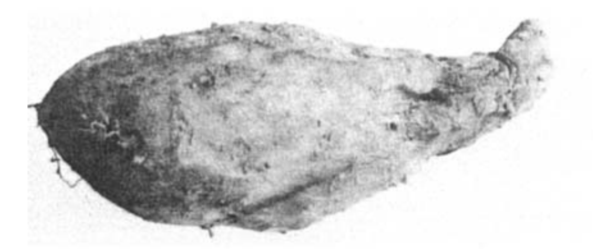


Fig. 9.197. Cylas formicarius (Sweet Potato Weevil) Adults, larva and damaged tuber.





Cylas puncticollis Boh.

Common name. African Sweet Potato Weevil
Family. Apionidae (Curculionoidea)
Hosts (main). Sweet potato
(alternative). Some other species of *Ipomoea*, and also maize; and sesame.
Damage. The larvae bore in the stems and tubers, which eventually develop extensive rotting patches, and the adults sometimes eat the leaves.
Pest status. A serious pest of sweet potato in tropical Africa, partly because of the direct damage done to the tubers, but also because of the associated rots which mean that damage continues during storage after harvest.
Life history. See under *C. formicarius*.

The adults are slightly different from the previous species in that they are entirely black in colour. In both E. and W. Africa many infestations of sweet potato tubers contain both species of *Cylas*.

Distribution. This species is confined to tropical Africa, mostly E. and W. Africa (CIE map no. A279).
Control. Continuous cropping of sweet potato can keep the weevil populations very high and so crop rotation is recommended. Varietal resistance to weevil infestation has been both claimed by some workers and denied by others as being only very short-lived, and so at present its possible value is dubious. Destruction of infested crop material and crop residues will also help to lower pest populations.

In W. Africa a fungus (*Beauvaria* sp.) has been found to attack the adult weevils during the rainy season.

Foliar sprays of insecticides have generally been of little use, but the dipping of planting slips in a DDT solution gave good control in Uganda. DDT and BHC dusts used at planting have also given good control. Dipping and dusting has to be done with care for if the chemical is too strong phytotoxicity may result.

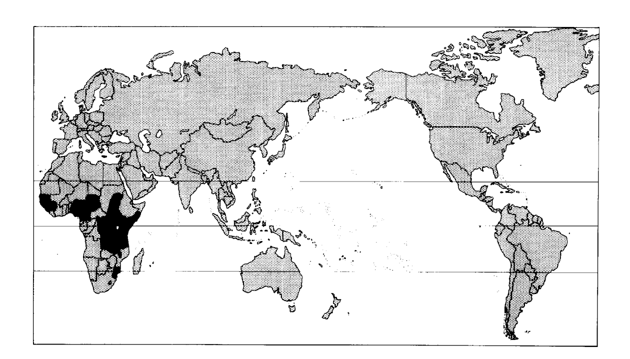
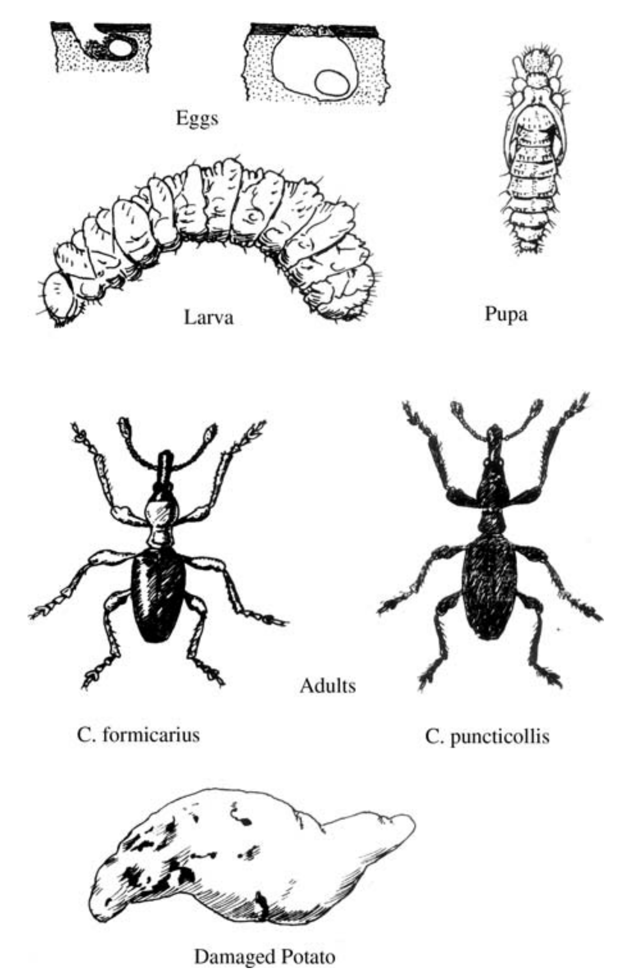


Fig. 9.198. Cylas puncticollis (African Sweet Potato Weevil); Kenya.



Araecerus fasciculatus De Geer

Common name. Coffee Bean Weevil; Nutmeg Weevil
Family. (Curculionoidea) Anthribidae
Hosts (main). Nutmeg
(alternative). Coffee beans, cocoa beans, dried cassava, seeds of various types, both in the field and in storage.
Pest status. Most serious as a stored products pest, but field infestations are common; in Hong Kong field infestations of nasturtium seeds are heavy.
Life history. Eggs are laid singly on the ripening, or fully ripe, seeds, and the white, legless larvae burrow. Each ♀ lays about 50 eggs into the seeds, each larva usually spending its immature life inside the same seed. Pupation takes place with the seed.

The adult is a small brown beetle about 3–5 mm in body length; it looks rather like a bruchid in appearance but has distinctively clubbed antennae. Adults fly strongly, and in Hong Kong are serious domestic pests where they can be seen flying into flats and houses during the day at certain times of the year.
Life cycle takes 46–66 days at 28°C and 70% RH. Adults live for up to 4 months.
Distribution. Cosmopolitan throughout the warmer parts of the world; it is found quite regularly in warehouses in the UK but generally fails to survive the winter.
Control. Generally not required, as field infestations are usually light, and warehouse infestations are generally controlled by the regular fumigations.
Another species of *Araecerus* is *A. levipennis* Jordan found in Hawaii and called the Koathaole seed beetle;
A. spp. in India on several hosts; *A. crassicanis* in legume pods; Indonesia.

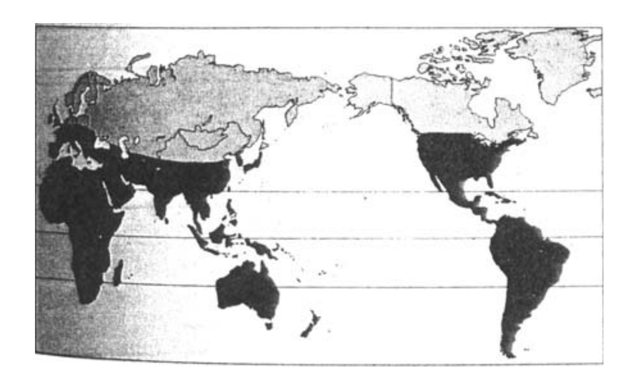
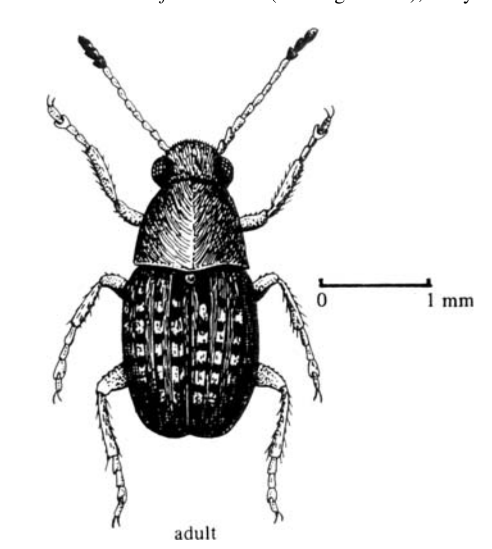
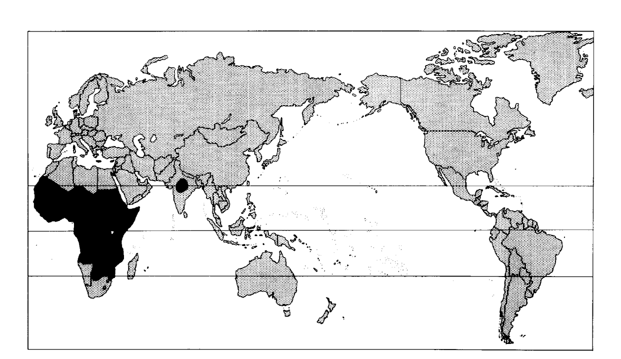


Fig. 9.199. Araecerus fasciculatus (Nutmeg Weevil); Kenya.



Alcidodes dentipes (Oliver)

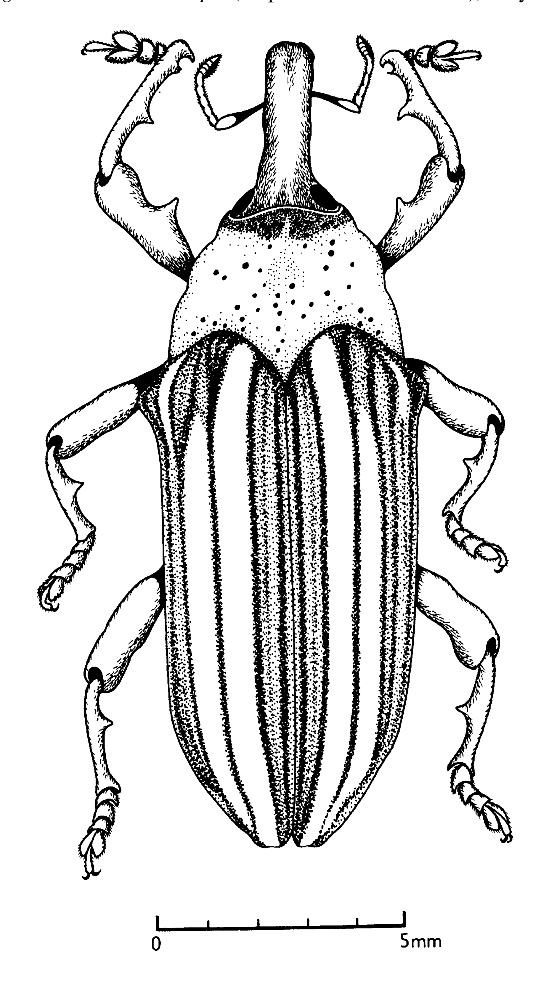
Common name. Striped Sweet Potato Weevil
Family. Curculionidae
Hosts (main). Sweet Potato, and groundnut.
(alternative). Cotton, and other woody legumes.
Damage. The adult weevil girdles the stem of the plants just above ground level; the plants then wilt and die. The larvae bore inside the stem, making galls.
Pest status. Sometimes a serious pest of sweet potato, but usually only a minor pest of groundnut and cotton.



Alcidodes gossypii is the Cotton Stem-girdling Weevil.
Life history. The larvae are believed to feed inside the pith of the stem, forming visible galls.

The adult weevil is of moderate size, being about 14 mm long, and is conspicuously striped longitudinally along the elytra, and it has pronounced spines on the inner edge of all tibiae and also on the fore-femora.
Distribution. Tropical Africa and India.
Control. Not usually required.

Fig. 9.200. Alcidodes dentipes (Striped Sweet Potato Weevil); Kenya



Weevils (Coleoptera; Curculionidae)

A very large group of beetles, containing more than 60000 species, worldwide in occurrence, equally well distributed throughout the tropics and temperate regions, and many are pests of cultivated crops and forest trees. There is some diversity of life-styles that makes generalization a little difficult, but there is an overall similarity.

All the larvae show great morphological similarity, being fat-bodied, sluggish, legless, whitish in colour with a brown well-sclerotized head capsule, and well-developed mandibles. They are most frequently to be found in the soil where they bite and chew fine roots and sometimes the root damage is sufficient to warrant their categorization as pests. Some larvae burrow into the root nodules of Leguminosae (*Sitona*), some bore into the tap root, some bore into herbaceous stems and rhizomes (banana weevils: coconut weevils; Sisal Weevil). A few larvae are aquatic, and some are leaf-miners in dicotyledonous plants. Others make globular galls in herbaceous stems (Cabbage Stem Weevil), or in root crops (Turnip Gall Weevil), or corms (*Otiorhynchus*). Many species develop inside seeds and grains (Hazelnut Weevil; Cabbage Seed Weevil; *Sitophilus*) and a few inside unopened flower buds (blossom weevils), and others inside developing fruits (Cotton Boll Weevil; Mango Seed Weevil). The pantropical palm weevils (*Rhynchophorus*) have larvae that bore the crown of palms, destroying the growing point, and may eventually bore right through the trunk. Another rather specialized case is the Tea Root Weevil in Africa, whose larvae tunnel the roots of woody shrubs (tea, coffee, etc.) and often ring-bark them, killing the entire bush. Several genera are timber borers and they tunnel the sapwood of crops such as cashew (Cashew Weevil) in Africa; there are many species in *Pinus* and other conifers, and some in deciduous trees (oak, alder, birch, etc.), and these are forestry pests of some consequence.

Adult weevils may be roughly divided into two groups: 'broad-nosed' weevils and 'snouted' weevils with a long rostrum and terminal mouthparts. The 'broad-nosed' weevils are foliage eaters; some make regular peripheral feeding notches in the leaf margin (*Systates*; *Sitona*), others tend to make holes in the lamina of the leaf, or else leave ragged-edged feeding scars on the leaf edges (*Phyllobius*; *Otiorhychus*).

The 'snouted' weevils usually (in the case of the females) combine the act of feeding with the preparation of an oviposition site. The long rostrum is used to make a deep excavation into the host plant tissues, the female feeds whilst excavating the hole, then she turns round and lays an egg there. The larva then develops *in situ*, in the shoot, stem, fruit, seed, etc. This is shown particularly well in the case of the palm weevils (*Rhynchophorus*), and the Chinese Bamboo Weevil (Hill, 1983; p. 484). Species of *Alcidodes* are known as stem-girdling weevils in that the adults eat the stem bark, usually girdling the stem just above ground level.

Pupation usually takes place in the soil, except for the deep plant tissue borers which remain inside the stem/fruit/seed to pupate. Thus infested fruits/seeds show a characteristic emergence hole through which the young adult has departed.

Important pest species of weevils

In addition to the species already included in this chapter, there are other important pest species that require mention.

Alcidodes spp. – (Stem-girdling Weevils) several hosts; Africa and India.
Baris spp. – (Melon Weevils, etc.) larvae bore fruits of Cucurbitaceae in the Mediterranean Region; also pineapple in S. America.
Conotrachelus nenuphar Herbst – (Plum Curculio) on top fruits; USA and Canada.
Conotrachelus spp. – (Quince/Butternut/Black Walnut Curculios) USA.
Cosmopolites sordidus (Germ.) – (Banana Weevil) pantropical (CIE map no. A.41).
Curculio sayi – (Small Chestnut Weevil) on Sweet Chestnut; USA.
Cyrtotrachelus longimanus – (Bamboo Weevil) China.
Diocalandra spp. – (Coconut Weevils) Old World tropics (CIE maps nos. A.248 and 249).
Listroderes costirostris (Klug) – (Vegetable Weevil) polyphagous; S. America and USA.
Listronotus oregonensis (LeC.) – (Carrot Weevil) USA.
Lissorhoptrus spp. – (Rice Water Weevils) USA, S. America, and now Japan.
Lixus spp. – (Beet/Cabbage Weevils) Mediterranean Region and Asia.
Lixus concavus Say – (Rhubarb Weevil) USA.
Odoiporus longicollis (Oliv.) – (Banana Stem Weevil) tropical Asia and the Pacific Islands.
Magdalis spp. – (Bark Weevils) larvae bore under tree bark, adults hole leaves; on many fruit trees, elms, etc.; Europe, USA.
Myllocerus spp. – (Grey Weevils) polyphagous; India and Asia.
Polydrusus spp. – (Leaf Weevils) on fruit and nut trees, larvae in the soil; Europe.
Rhynchophorus (Palm Weevils) pantropical (CIE maps nos. A.258 and 259).
Pissodes spp. – (Conifer Weevils) Asia, Canada, USA.
Sphenophorus spp. – (Billbugs) mostly on cereals; Canada and USA.
Sternochetus spp. – (Mango (Seed) Weevils) Old World tropics (CIE map no. A.180).
Systates spp. – (Systates Weevils) throughout Africa.
Tachypterellus spp. – (Apple/Cherry Curculios) USA.
Trichobaris spp. – (Potato Stalk Borers) Canada.
Tychius spp. – (Clover Seed Weevils) Canada.

Control of weevils

Adults. Generally persistent contact or stomach poisons have to be used, both as foliar sprays and on the mulch underneath, for the control of adults. The successful insecticides have been DDT, HCH, aldrin, dieldrin, as well as carbaryl, chlorpyrifos, fenitrothion and toxaphene

Larvae. Deep-boring larvae have been killed in many hosts by injecting the infested tunnel galleries with demeton-*S*-methyl, paradichlorobenzene, carbaryl or oxydemeton-methyl.

Larvae in the soil have been successfully killed by the use of seed dressings, sprays, dusts, and granules of the insecticides aldrin, dieldrin, DDT, chlorpyrifos, carbaryl and fenitrothion.

Anthonomus grandis Boh.

Common name. Cotton Boll Weevil
Family. Curculionidae
Hosts (main). Cotton
(alternative). Wild species of *Gossypium*, *Abutilon* spp., *Hibiscus* spp., and *Thurbaria thespesioides*, and maize.
Damage. The larvae bore into the bolls and squares; the squares turn yellow and die. Most punctured squares and small bolls are shed. Large, punctured bolls are not shed but the locus on which the larva feeds fails to develop properly, and the lint becomes cut, stained and decayed.
Pest status. A serious pest of the cotton-growing areas of the USA and Mexico where crop losses can be high.
Life history. Eggs are laid singly in deep punctures within the squares or bolls. Incubation requires 3–5 days.

The larvae feed in the squares and bolls for 7–14 days, and then they pupate. Pupation takes 3–5 days and the adults cut their way out of the squares.

The adult weevils spend the winter in soil litter and trash. In the spring they return to the cotton fields, and stay there until the first frosts. The adults feed on the squares and flowers, or bolls, and after 3–4 days the females start egg-laying.

The life-cycle takes only about 21 days, and there may be seven generations per year.
Distribution. Southern USA, Mexico, C. America, W. Indies, and S. America (Venezuela and Colombia) (CIE map no. A12). Now recorded in Brazil (1984) and Paraguay (1988).
Control. Cultural practices which help to reduce boll weevil populations include: using good fertile land with sufficient fertilizer, the growing of early maturing varieties, early planting with close spacing, frequent cultivation, picking the crop early and cleanly, and finally the destruction of crop residues. Intercropping with maize has been suggested.

Chemical sprays recommended are: BHC, toxaphene, aldrin, and dieldrin, but care has to be taken with their use or else other pests may become more troublesome.

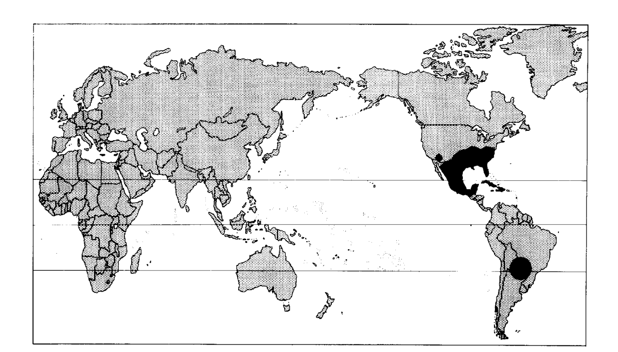
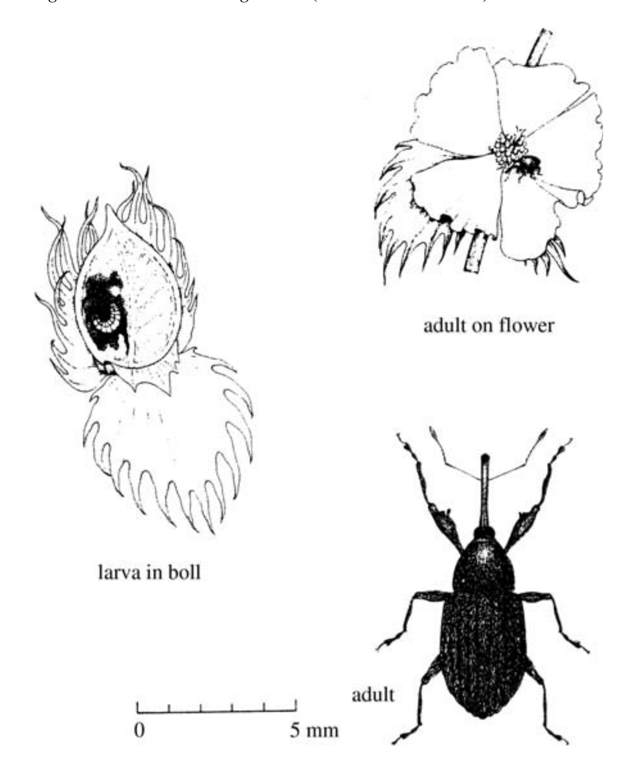
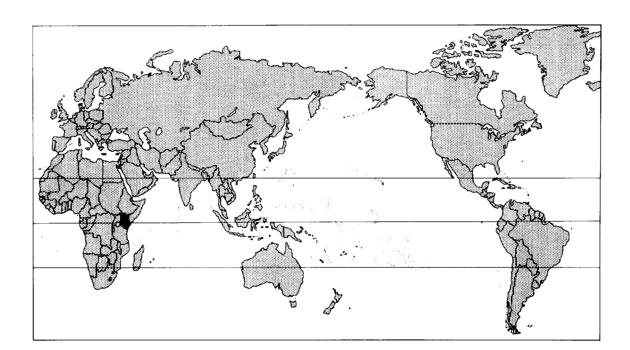


Fig. 9.201. Anthonomus grandis (Cotton Boll Weevil).



Aperitmetus brunneus (Hust.)

Common name. Tea Root Weevil
Family. Curculionidae
Hosts (main). Tea
(alternative). Coffee, beans, *Brassica* spp.
Damage. The larvae feed on the tap root, gnawing channels the length of the root, causing wilting, stunting, and eventual death of the young plant. Stems of young plants may be ring-barked at ground level by the larvae. Adult weevils feed on the foliage and chew irregularly shaped holes through the surface and also chew the leaf edges.
Pest status. In Kenya this is a serious pest in tea nurseries, where losses of 30–50% are not uncommon.



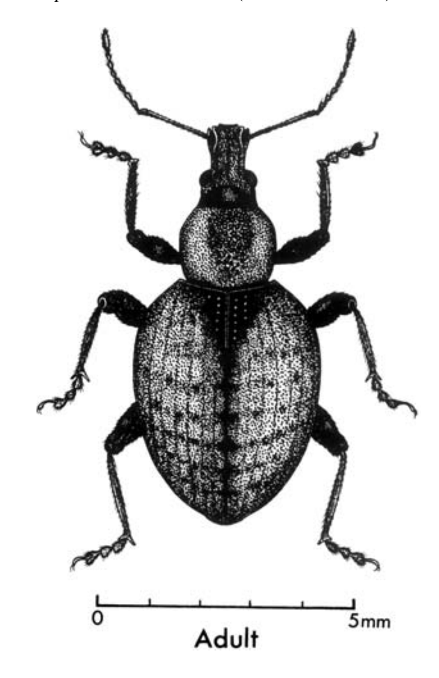
Life history. Life history details are not available.

The larvae of this weevil feed on the roots, particularly of seedlings where they feed on the tap root.

The adult is a distinctive black weevil about 7–9 mm long, which feeds on the leaves of tea and other plants. It looks rather like a *Systates* weevil, but has pale grey scales on its body.
Distribution. Only recorded from Kenya.

Twenty-seven species of weevils have been recorded feeding on the roots and leaves of tea bushes, in nurseries and recently established gardens. The other main pests are *Nematocerus* spp., and *Entypotrachelus meyeri* Kolbe.
Control. Foliar sprays dieldrin have generally been effective against the adult weevils.

Fig. 9. 202. Aperitmetus brunneus (Tea Root Weevil).



Cosmopolites sordidus (Germ.)

Common name. Banana Weevil
Family. Curculionidae
Hosts (main). Bananas (*Musa* spp.).
(alternative). Recorded from cocoa stems.
Damage. The larva bores irregular tunnels in the rhizome and pseudostem at ground level. The tissue at the edge of the tunnels turns brown and rots. If the stem is small, the banana variety susceptible or the infestation very heavy, the plant will die.
Pest status. A major pest of bananas throughout the tropics, and in some areas it is still spreading.
Life history. The eggs are laid singly in small pits made in the pseudostem near ground level by the female weevil; they are elongate-oval, white, and about 2–3 mm long. Hatching takes 5–8 days.

The larva is a white, legless grub with a brown head capsule. The larva period occupies 14–21 days.

Pupation takes place in holes bored by the larvae; the pupal period lasts 5–7 days. The pupa is white and about 12 mm long.

The newly emerged beetle is brown, turning almost black after a few days. Its normal food is dead or dying banana plants. It does not usually fly and may live for up to two years. Each female may lay 10–50 or more eggs over a period of up to 2 years. They are nocturnal in habits.
Distribution. Pantropical but with some areas not inhabited (CIE map no. A41).

C. minutus occurs in the Pacific region.
Control. Cultural methods are the most important and in many areas will be sufficient to keep the population level down. These methods include the use of clean suckers only; old stems should be cut off at ground level and the cut rhizome covered with impacted soil; old stems should be cut into strips and used for mulch; and good weed control.

The most successful insecticides for use against this pest are aldrin and dieldrin, applied as a dust around the bases of the pseudostems, and applied to the cut surfaces of the rhizomes before they are covered with soil. Planting suckers which are suspected of being infested should be dipped into dieldrin solution.

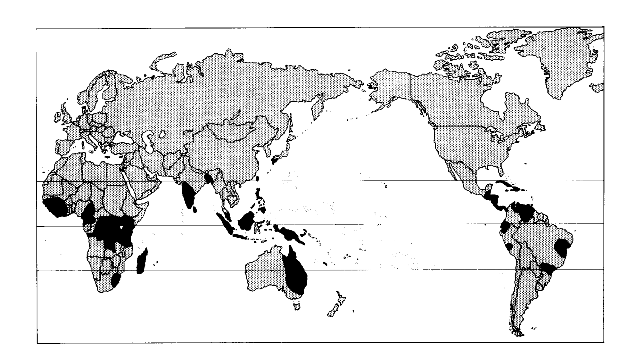
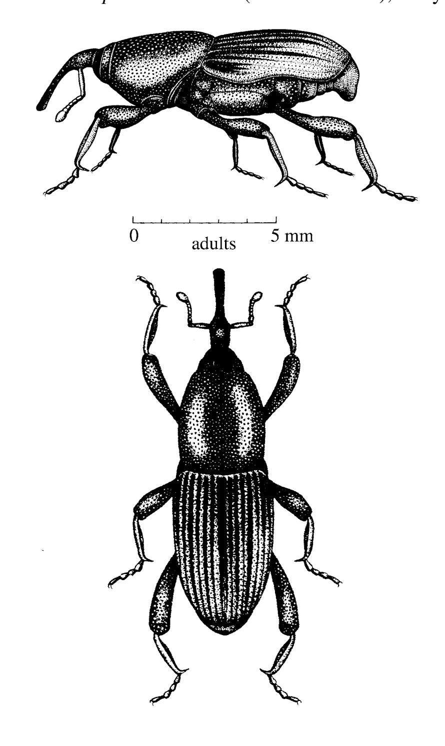


Fig. 9. 203. Cosmopolites sordidus (Banana Weevil); Kenya.



Cyrtotrachelus longimanus

Common name. Bamboo Weevil
Family. Curculionidae
Hosts. Various larger species of bamboos.
Damage. The larva develops in the apical shoot, which is entirely eaten away, thus terminating the growth of that stem and initiating lateral bud development, causing terminal branching. The feeding/oviposition site is marked by a ragged hole on the stem.
Pest status. A serious pest of bamboo grown for constructional purposes in southern China.
Life history. The female weevil feeds by biting into the apical shoot of the bamboo and after feeding she lays a single egg into the feeding site. The egg develops into a white, legless larva, with a brown head capsule and well-developed jaws – a typical weevil larva. The feeding larva destroys the apical shoot entirely, and after about four weeks, and attaining a body length of 4–5 cm, it drops out of the stem and pupates in the soil. During the feeding process the larva is protected and shielded by the stiff leaf-scales that normally protect the growing point.

The pupa overwinters inside an earthen cocoon in the soil, and usually the whole pupal period lasts for about ten months.

In S. China the adults are generally only seen in July and feeding larvae found in August, although it is thought that occasionally there might be a second infestation period in early October. Usually the damaged bamboos have a second period of growth in November which to some extent compensates for the damage done in July/August.
Distribution. To date only recorded from southern China, but similar species are seen in Borneo and Malaya.
Control. No details are known as to whether control is attempted in China.

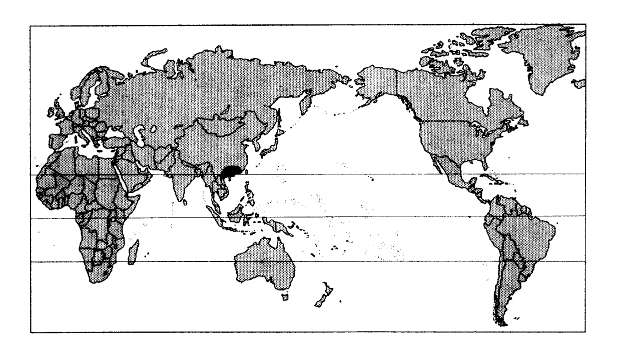
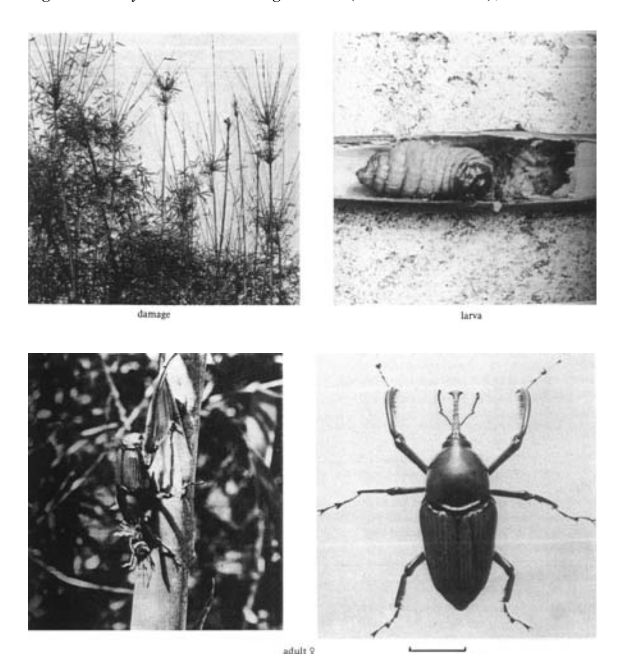


Fig. 9.204. Cyrtotrachelus longimanus (Bamboo Weevil); S. China.



Diocalandra spp.
D. frumenti (F.)
D. taitense (Guet.)

Common name. Four-spotted Coconut Weevils
Family. Curculionidae
Hosts (main). Coconut palm
(alternative). Date, oil, and nipa palms; also sorghum.
Damage. The larvae attack all parts of the palm, especially roots, leaves and fruit stalks, and cause premature fruit-fall. The leaf bases are bored from the trunk out to the leaflets. In some areas the trunk is also bored, at all heights.
Pest status. The precise status of these weevils as pests is open to dispute; some entomologists believe that the damage is primary and results in appreciable crop losses, but others maintain that this damage is purely secondary.
Life history. Eggs are laid in crevices at the base of the adventitious roots, at the foot of the trunk, or in the flowers, in the petiole, or at the base of the peduncle. Incubation takes 4–9 days.

The larvae bore into the tissues and cause gum to exude from the opening of the gallery. Larval development takes 8–10 weeks.

Pupation takes place within the larval gallery, taking some 10–12 days, but no cocoon is made.

The adults are small weevils, about 6–8 mm in length, shiny blackish, with four large reddish spots on the elytra. Coloration varies somewhat and is not a reliable taxonomic character – the adults are only distinguishable to an expert. Sexual dimorphism is evident, as with many other weevils, by the shape of the posterior apex, and the length and thickness of the rostrum (‘snout’), the male rostrum being shorter, thicker, and more curved.

The life-cycle takes 10–12 weeks.

Distribution. Recorded from Tanzania, Somalia, Seychelles, Madagascar, S. India, Sri Lanka, Bangladesh, Burma, Malaysia, Thailand, Indonesia, Philippines, Papua New Guinea, West Irian, Hawaii N. Australia, Solomon Isles, Samoa, Caroline and Mariana Isles (CIE map no. A249 & A. 248).
Control. Cultural methods include the avoidance of knife slash marks on the trunks, and earthing-up the base of the trunk to cover the adventitious roots.

A braconid parasite (*Spathius apicalis* Westw.) reportedly destroys up to 40% of the weevil larvae, and the predatory beetle *Plasius javanus* Eric. (Histeridae) is important.

The application of tar to the roots and the base of the trunk, and spraying with dieldrin, is said to be successful.

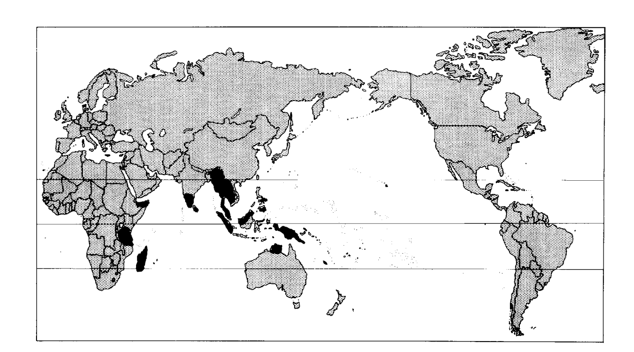
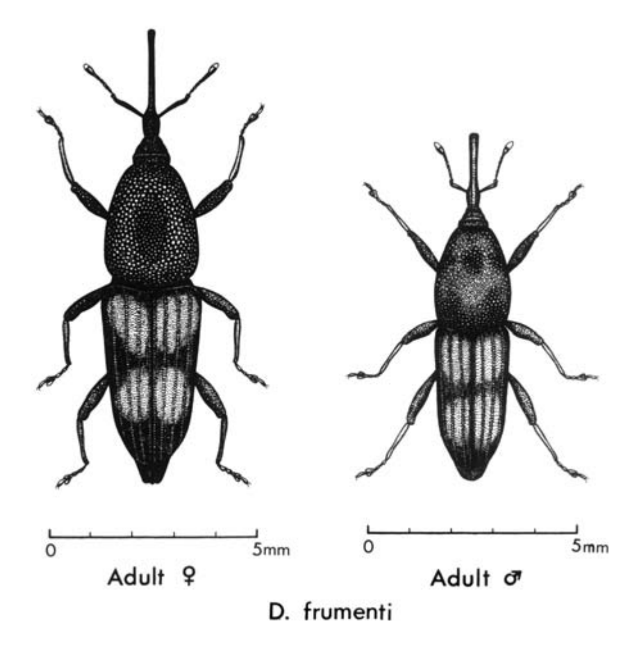


Fig. 9.205. Diocalandra frumenti (Four-spotted Coconut Weevil), ♂ and ♀.



Graphognathus spp.

Common name. White-fringed Weevils
Family. Curculionidae
Hosts (main). Cotton, pulses, sweet potato.
(alternative). Totally polyphagous, recorded from 380 species of host plant.
Damage. The larvae are the major pests, living in the soil they feed on the plant roots; adults feed on the foliage and do occasionally defoliate the plants.
Pest status. The larvae are quite serious polyphagous soil pests, and in the USA quarantines have been established to prevent their spread; the adults are really only minor pests.
Life history. The females are parthenogenetic and flightless, and lay their eggs on the soil surface 5–25 days after emergence; each female can lay up to 1500 eggs, often in groups of up to 60; egg-laying continues for two months. Incubation takes 11–30 days.

The larvae live in the soil and feed on plant roots, and overwinter as larvae, although some eggs may also overwinter in sheltered locations.

Pupation takes place in the soil in an earthen cell in the following spring. Adults (all females) emerge in May (USA) and being wingless do not disperse far, so heavy infestations may build up locally. The adults are typical broad-nosed weevils, about 12 mm long, dark grey in colour with conspicuous white lateral edges to the elytra. Adults are quite long-lived and survive for 3–4 months.

There is only one generation per year.

Distribution. This genus is S. American in origin and was first recorded in Florida in 1936. It has since spread throughout southeastern USA, and also New Zealand, Australia, and S. Africa (1941).

The species concerned are *Graphognathus leucoloma* (Boh.) which occurs as five distinct races (*dubious, fecundis, imitator, pilosus* and *striatus*) (CIE map no. A.179); *G. minor* (Buch.) and *G. peregrinus* (Buch.).

Control. In the USA quarantine measures are employed to prevent further spread of these pests; often using fumigation of plant materials.

Cultural control measures include planting of oats or other small grains in infested ground, and rotations that incorporate legumes only once in 3–4 years. Discing and harrowing generally reduces the numbers of larvae and pupae in the soil.

Insecticides found to be effective include DDT, aldrin, dieldrin, heptachlor, and chlordane, incorporated into the top 10 cm of the soil or sprayed on the foliage. Present chemical recommendations include soil fumigation with D-D, or methyl bromide and carbon disulphide.

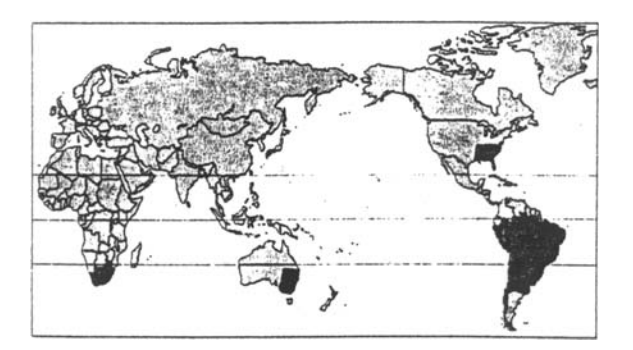
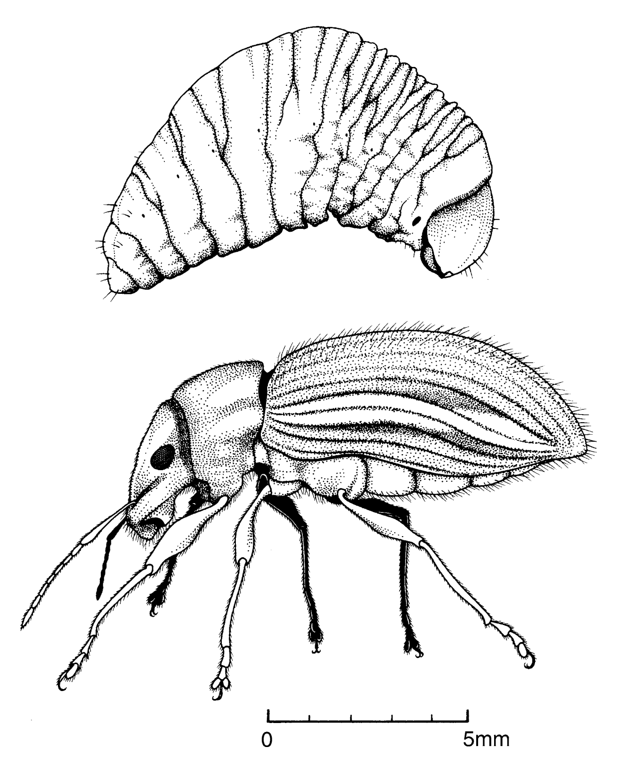


Fig. 9.206. Graphognathus sp. (white-fringed Weevil), larva and adult.



Hypera spp.
(= *Phytonomus* spp.)

Common name. Alfalfa (Clover Leaf) Weevils
Family. Curculionidae
Hosts (main). Alfalfa, clovers, trefoils.
(alternative). Other Leguminosae.
Damage. Larvae feed exposed on the tips of foliage at night, eating buds and stem tips, and also the leaf lamina. Flower bud destruction is important in seed crops. Adults make small feeding holes in the leaves.
Pest status. Serious pests of forage legumes in temperate regions; injury usually most severe in dry seasons.
Life history. Eggs are laid in the spring in holes eaten in the stems or buds by the females; from 1–40 eggs are laid per cavity, and each female lays from 200–800 eggs. Some species lay only 200–300 eggs and these are usually laid singly. Incubation takes 2–3 weeks.

The hatching larvae feed *in situ* inside the stem for 3–4 days, then they move to the shoot tips where they feed concealed in the folded leaflets and buds. Later they tend to feed on the opened leaves and may eat all the lamina except for the main veins. Larval development takes 20–60 days, when a size of 2–3 mm is reached; body colour is generally greenish.

Pupation takes place in a spun cocoon either in the foliage or else in the soil; development takes about three weeks.

Young adults emerge and then feed on the foliage for a while before hibernating in a sheltered location. In the spring the adults become active in March and April (in Europe) and feed on the foliage for a time before laying eggs. The adult is a small weevil, some 3–6 mm in length, greyish-brown in colour with distinctive longitudinal striping; the snout is rather short.

There is only one generation per year.

The different species do tend to have a slightly different biology and habits.
Distribution. The main species concerned are as follows:
Hypera nigrirostris (F.) – (Clover Leaf Weevil) Europe, Japan, Canada, USA.
H. postica (Gyll.) – (Alfalfa Weevil) Europe, Asia, N. Africa, Canada and USA (CIE map nos. A.304 and 456).
H. punctata (F.) – (Trefoil Leaf Weevil) Europe, Canada, USA.
H. meles (F.) – (Clover Head Weevil) Canada and USA.

In the UK 16 species of *Hypera* are recorded, most from Leguminosae.
Control. In Canada these weevils are quite heavily parasitized and also attacked by a fungus that appears to be of importance in regulating numbers.

The most successful insecticide has been DDT as a heavy spray about 10–14 days after the first cut and before the flower buds appear.

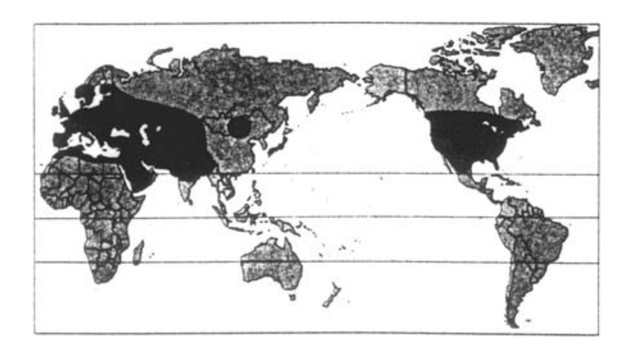
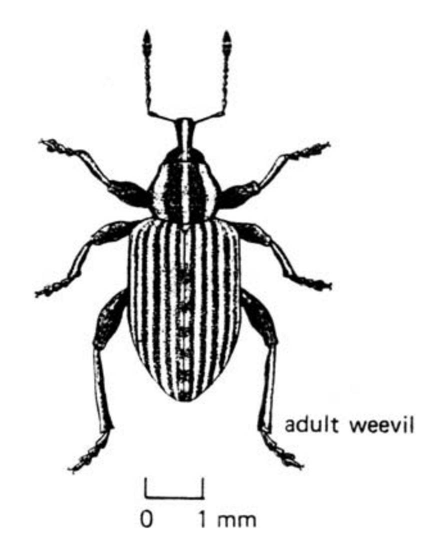


Fig. 9.207. Hypera postica (Alfalfa Weevil).



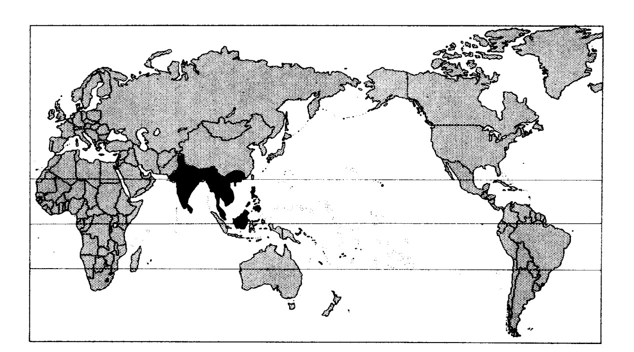
Hypomeces squamosus (F.)

Common Name Gold-dust Weevil
Family Curculionidae
Hosts (main). *Citrus* spp. and Sweet Potato (adults)

(alternative). Other species of *Ipomea* and a wide range of other plants.

Larvae damage the roots of tobacco. maize, sugarcane, upland rice, etc.

Damage Adults eat notches out of the leaf margin, and occasionally defoliate young bushes. Larvae in the soil eat living plant roots.
Pest Status A common and widespread pest in S.E. Asia and India on several different crops, but seldom serious; larval damage to plant roots is usually difficult to assess.
Life History The larvae live in the soil and feed on living plant roots, and pupation takes place in the soil.
The species appears to be univoltine.



Adults are broad-nosed weevils anout 10–15 mm long, greyish in colour and with the body surface covered with a fine golden-green 'dust'. The colour is imparted by tiny flattened circular iridescent setae. Adults are long-lived.
In most parts of the world there are different broad-nosed weevils that inflict almost identical damage on the foliage of their host plants by eating notches out of the edge of the leaf lamina. In all cases this damage is done by the adults and in most cases the larvae live in the soil and eat plant roots. These weevils include *Hypomeces* spp. in S.E. Asia, *Myllocerus* spp. in India, *Systates* spp. in Africa, and *Sitona* spp. in Europe and N. America, etc.
Distribution Found throughout India and S.E. Asia, and the Philippines, but very similar species occur as mentioned above.
Control Generally control is not required, but if it should be then the recommendations for Chafer control could be applied.
A larger species (17–18 mm) is found in Indonesia (*H. inflatus*) on maize, cotton, groundnut, etc.

Fig. 9.208. Hypomeces squamosus (Gold-dust Weevil); S. China.



Lissorhoptrus oryzophilus Kusch.
(= *L. simplex auctt***.)**

Common name. Rice Water Weevil
Family. Curculionidae
Hosts (main). Rice
(alternative). Various grasses and sedges.
Damage. Rice is attacked by both adults, feeding on the leaves, and larvae on the roots. The adults leave long scars on the leaf where the surface layers have been eaten. Larval damage is the more important, for the larvae eat the roots resulting in delayed crop maturity, stunting of plants and loss of grain yield.
Pest status. A serious pest of rice in the rice-growing areas of the USA, and also in Alberta, Canada.
Life history. Eggs are laid under water on the basal half of the submerged part of the leaf sheath, and occasionally on the roots. Each female may lay up to 35 eggs. The eggs hatch in 7–10 days.

The white larvae, with reduced legs, and brown head capsule, feed on the roots of the rice plant, and can apparently move as much as 15 cm through the soil. The larvae have paired dorsal hooks modified (spiracles) on the abdominal segments used for obtaining air from the plant roots. There are four larval instars, which take about 50 days to complete.

Pupation takes place in an earthen cocoon attached to the roots, and takes about 21 days.

The adults are small, broad-nosed weevils; when newly emerged they fly at night to adjacent fields of young rice. The over-wintering period is spent by the adult in grass or rice stubbles.

The entire life-cycle takes about 78 days in California: there are two generations per year there.
Distribution. Eastern and southern states of the USA and California; and Alberta, Canada (CIE map no. A270). Now established in S. Japan (Kyushu).

Several other species of *Lissorhoptrus* are found attacking rice in S. America.

Control. Draining and drying of the rice fields is effective as a control measure but is generally not economically feasible.

Insecticides used as sprays, granules or seed dressings have been effective; the most successful method being aldrin as a seed dressing.

Carbofuran granules kill both adults and larvae - most effective broadcast 25 DAG.

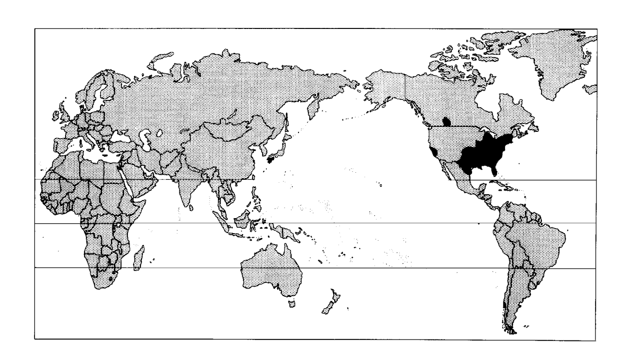
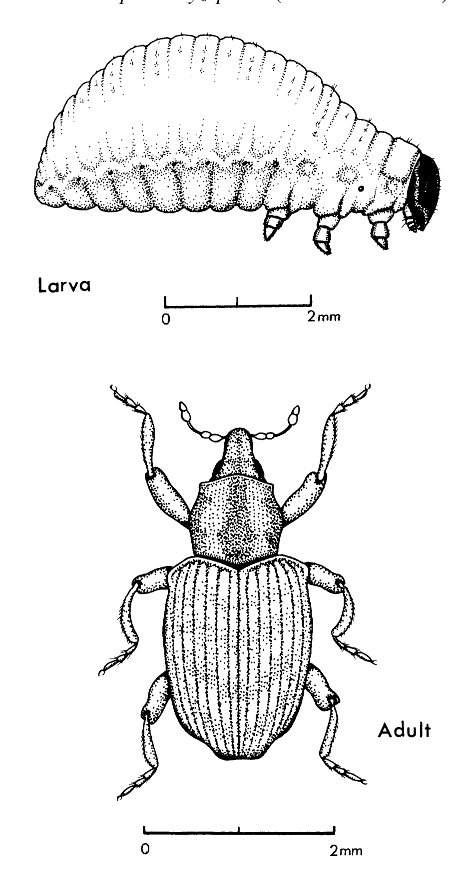


Fig. 9.209. Lissorhoptrus oryzophilus (Rice Water Weevil).



Mecocorynus loripes Chevr.

Common name. Cashew Weevil
Family. Curculionidae
Hosts (main). Cashew trees.
(alternative). *Afzelia* sp. (Caesalpiniaceae).
Damage. The larva bores in the sapwood of the tree. Brown-black gummy frass is seen on the trunk and main branches; in severe attacks the tree may die.
Pest status. This is usually only a minor pest of cashew in Coast Province, Kenya, but neglected plantations are liable to be severely attacked.
Life history. Eggs are laid singly in small holes by the female weevil in the bark of the trunk or branch.

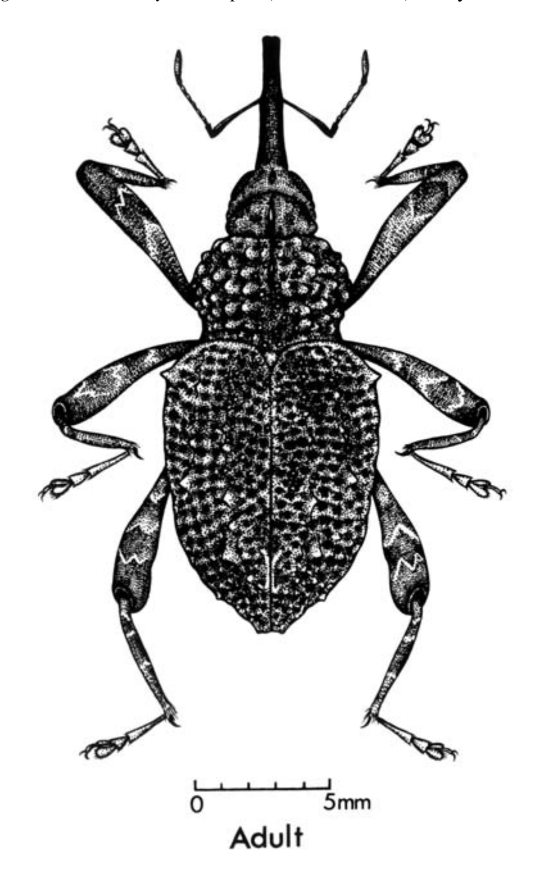
The larva is a legless grub, whitish in colour with a brown head. It bores through the bark and moves downwards feeding on the sapwood of the tree. At intervals it makes frass-ejection holes to the exterior. Heavily infested trees become ringed by damaged sapwood and eventually die. When the larva becomes full-grown it constructs a pupal chamber about 2 cm below the bark. The tunnel from the chamber to the exterior is stuffed with wood fragments before pupation.

The adult is a dark grey-brown weevil about 2 cm long, and of a knobbled appearance. It has fully developed wings but is not known to fly.

The complete life-cycle takes about six months.
Distribution. Kenya, Mozambique, and Tanzania only.
Control. Very severely infested trees should be destroyed, in the following manner. All adult weevils should be collected and destroyed; the tree should be felled and de-barked to expose all the larval galleries; all larvae and pupae should be killed; and after not more than two months the tree should be burned.

Lightly infested trees can be treated by killing all evident adults, cutting off bark to expose the larval and pupal galleries, and then removing and killing the larvae and pupae found. This treatment should be repeated every month for a further six months if required.

Fig. 9.210. Mecocorynus loripes (Cashew Weevil); Kenya



Nematocerus spp.

Common name. Shiny Cereal Weevils
Family. Curculionidae
Hosts (main). Maize, barley, wheat, and other cereals.
(alternative). Coffee, tea, beans, and many other crops and plants.
Damage. The adult weevils feed on the leaves, making characteristic notch-like damage to the leaf margin. In severe attacks there can be almost complete defoliation. The larvae live in the soil and eat the roots, the underground stem, and germinating seeds. Seedlings are preferred as host plants, and most damage is done to the stem between the seed and the soil surface, although older plants are attacked.
Pest status. A pest of sporadic importance in Kenya, and found on a variety of crops.
Life history. Eggs are laid in a fold in the leaves. On hatching the young larvae drop to the ground and burrow into the soil. The larvae are white, legless, and with a brown head capsule; about 12 mm long when mature.

Pupation takes place in an earthen cell in the soil.

The adult weevil is 6–12 mm long, and is shiny with smooth elytra which are fused together, so the adults cannot fly. When they emerge from the pupal cells they walk on to the nearest host plant.
Distribution. E. Africa, Ethiopia.
Control. Adults can be controlled by DDT dusts or sprays, but there are no insecticidal recommendations available for the larvae.

In E. Africa emphasis has been placed on various aspects of cultural control, such as the avoidance of double cropping, early planting, and application of fertilizer to marginal soils.

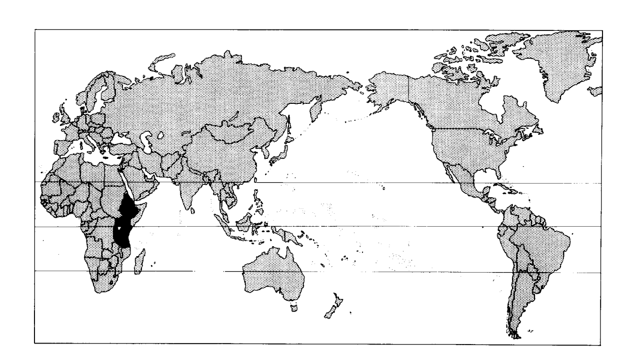
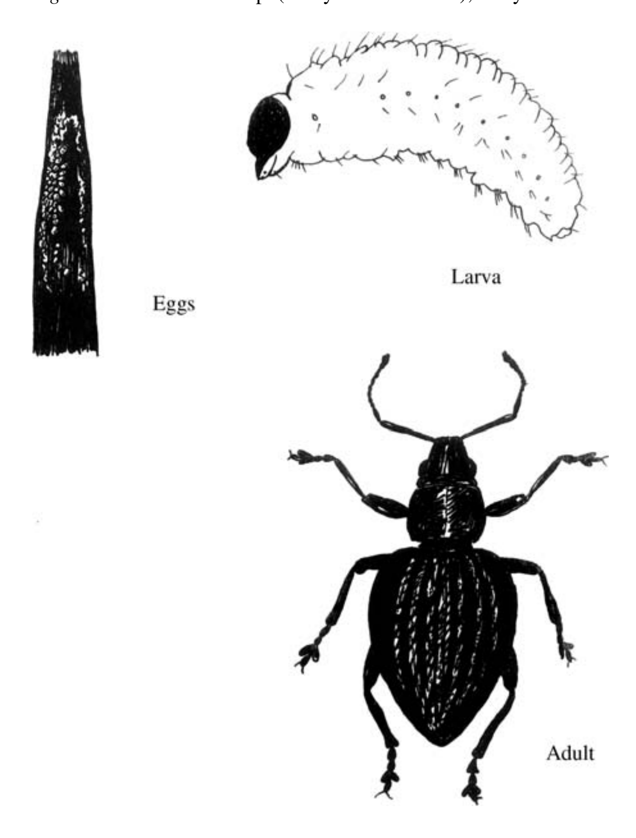


Fig. 9.211. Nematocerus sp. (Shiny Cereal Weevil); Kenya.



Odoiporus longicollis (Oliv.)

Common name. Banana Stem Weevil
Family. Curculionidae
Hosts (main). Bananas (*Musa* spp.).
(alternative). None recorded.
Damage. The larvae bore in the pseudostem and the peduncles of the fruit, and the tunnels often become infected with rots. In heavily attacked plants the pseudostem is severely weakened and easily breaks.
Pest status. A serious pest of bananas in S.E. Asia and India.
Life history. Eggs are laid singly in small cuts in the pseudostem and the young larvae bore straight into it. The burrowing larvae make long tunnels through the pseudostem and in some cases right up into the fruit bunch peduncles. In India and S.E. Asia some banana plants are attacked simultaneously by both species of banana weevil, so that both rhizome and pseudostem are tunnelled.

Pupation takes place inside a fibrous cocoon inside the pseudostem, and takes about a week.

The adult is a small weevil, brown after emergence gradually turning black, about 10 mm in length, with an elongate narrow snout. It is long-lived and feeds on the tissues of the banana plant, often being found in the larval galleries.
Distribution. India, and S.E. Asia extending to Papua New Guinea.
Control. As for *Cosmopolites sordidus*.

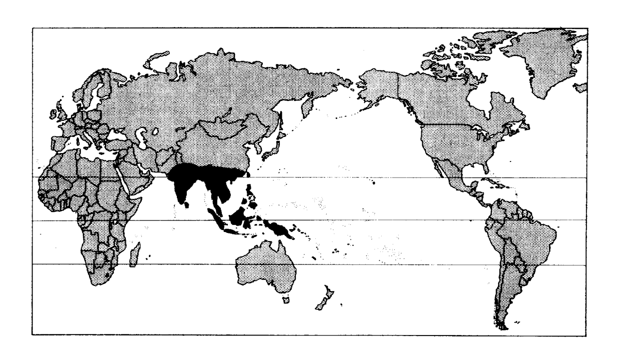
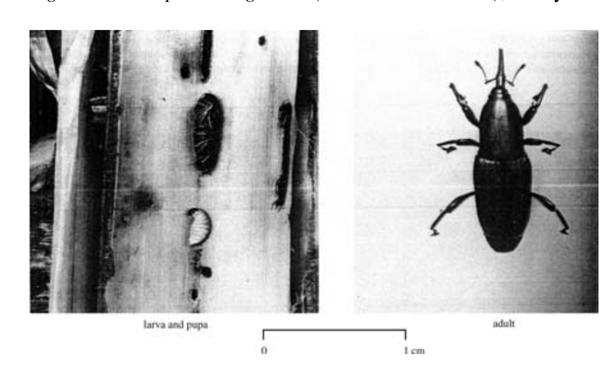
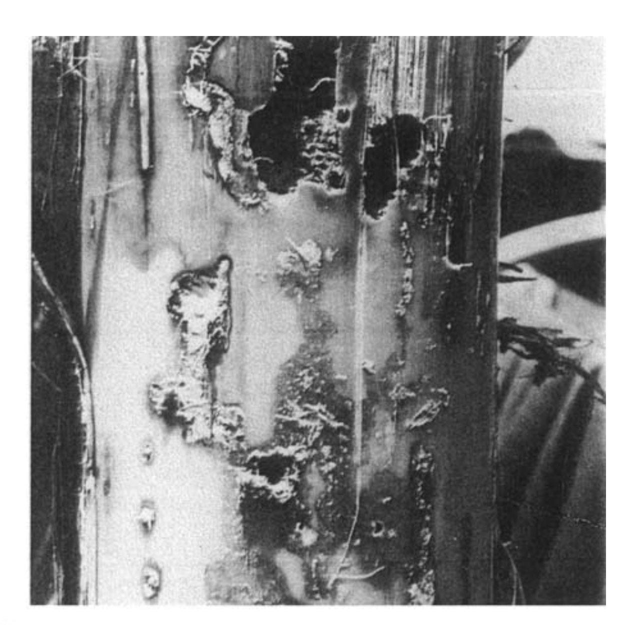


Fig. 9.212. Odoiporus longicollis (Banana Stem Weevil); Malaya.







damage

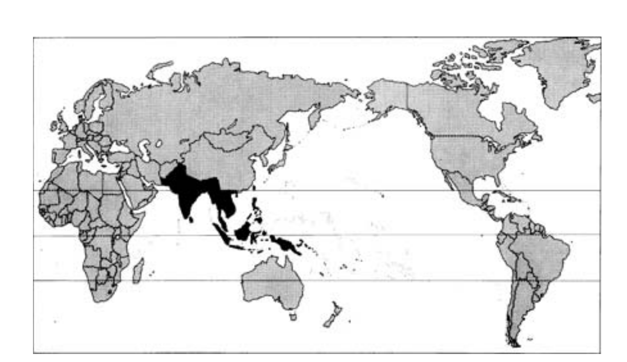
Rhynchophorus ferrugineus (Oliv.)
(= *R. schach* **Oliv.)**

Common name. Asiatic (Red) Palm Weevil; (Red Stripe Weevil)
Family. Curculionidae
Hosts (main). Coconut and oil palm.
(alternative). Date, sago, and other species of Palmae.
Damage. The feeding larvae bore the crown of the palm and may destroy it. Initially the outer leaves turn chlorotic and die; this gradually spreads to the innermost leaves. Later the trunk becomes tunnelled and weakened, and may break.
Pest status. A fairly serious pest of coconut and oil palm throughout S.E. Asia.
Life history. Eggs are laid in the crown of the palm, often in holes made by other insects (*Oryctes* spp. etc.), or by man; the females may actively search for cut petioles as oviposition sites. Each female may lay 200–500 eggs. Hatching takes place after about three days.

The larvae are yellowish-white, legless (apodous), rather oval in shape, with a reddish-brown head capsule; at maturity they are about 5–6 cm long. They penetrate the crown initially, and later to most parts of the upper trunk, making tunnels of up to 1 m in length. They are voracious feeders, and the damaged tissues soon turn necrotic and decay, resulting in a characteristic unpleasant odour. As the galleries become more extensive the trunk weakens and in a storm the tree may easily be decapitated. The larval period lasts 2–4 months, but has been recorded as only 24 days when feeding on the nutritious palm 'cabbage'.

Pupation takes place in a cocoon (80 × 35 mm) of fragments under the bark, the actual emergence hole being blocked with a fibrous plug. The pupal stage lasts for 14–28 days.

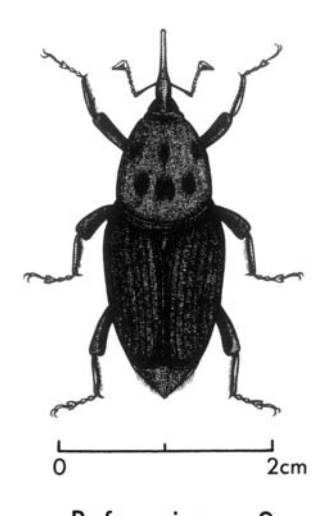
The young adult stays in the cocoon for 8–14 days before emerging and starting to feed. The adult beetle is a large (but smaller than the other species of *Rhynchophorus*) reddish-brown weevil some 32–34 mm in length (full range 25–50 mm), and this species has either spots or a stripe of red on the thorax. The variation in size and colour pattern has led to some taxonomic confusion, and the *R. schach* of Wood (1968) is thought to be a synonym and colour variation of *R. ferrugineus*.
Distribution. Pakistan, India, Sri Lanka, S.E. Asia, to China, Taiwan, and the Solomon Isles (CIE map no. A258).
Control. See under *R. palmarum*.





Damaged oil palm; Sarawak

Fig. 9.213. Rhynchophorus ferrugineus (Asiatic Palm Weevil)



Rhynchophorus palmarum (L.)

Common name. South American Palm Weevil
Family. Curculionidae
Hosts (main). Coconut and oil palm.
(alternative). Date, sago and other palms; also sugarcane.
Damage. The larvae burrow in the crown of the palm, feeding on the young tissues, and sometimes destroy the growing point, when the palm will die. The leaves turn chlorotic and die, and the trunk becomes tunnelled and weakened, and may break in a storm.
Pest status. A serious pest of palms in C. and S. America.
Life history. For details see *R. ferrugineus*.

The adult weevil is larger than the previous species being some 43–54 mm in length, on average, and is usually darker brown in colour, sometimes almost black. The usual weevil sexual dimorphism is clearly apparent in this genus.
Distribution. Recorded from Mexico, C. America, W. Indies, and the northern half of S. America (CIE map no. A259).
Control. Many cultural control methods can be applied against this pest in order to reduce the population size, such as elimination of breeding sites by restriction of physical injury to the palms, control of *Oryctes* etc., destruction of infested palms, trapping of adults, etc.

Recommended insecticides are aldrin and dieldrin sprayed on the crowns and trunks of the palms. Or, alternatively, demeton-*S*-methyl, para-dichlorobenzene, oxydemeton-methyl, or carbaryl, can be injected into the infested galleries, or the liquids can be injected into the trunk a little way above the infested region.

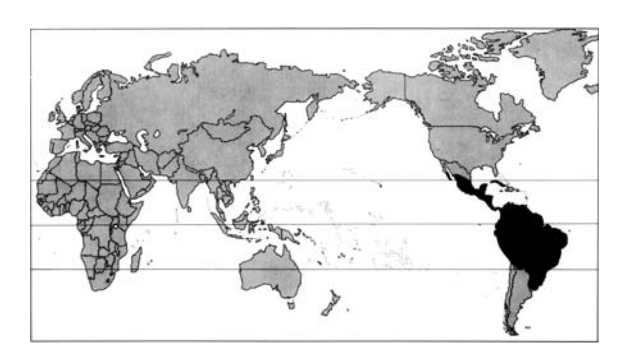
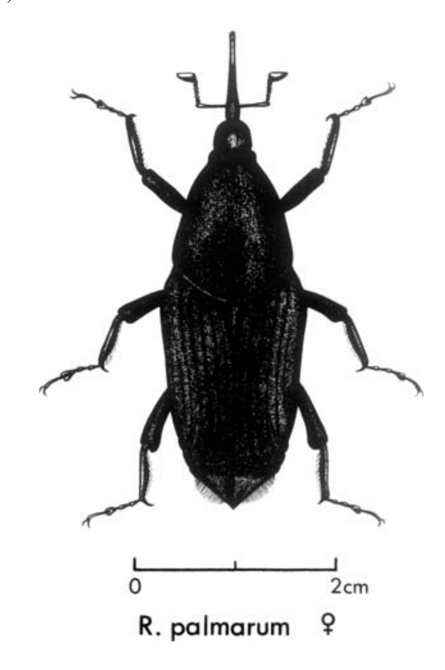
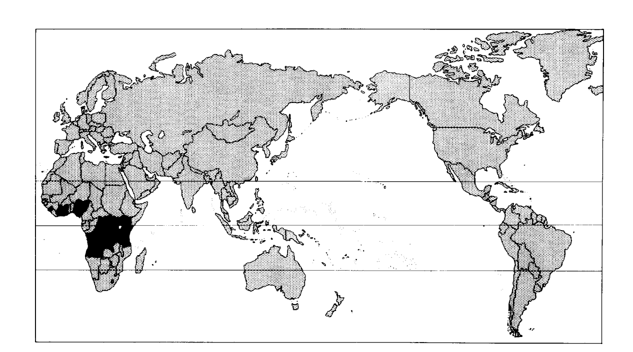


Fig. 9.214. Rhynchophorus palmarum (South American Palm Weevil).



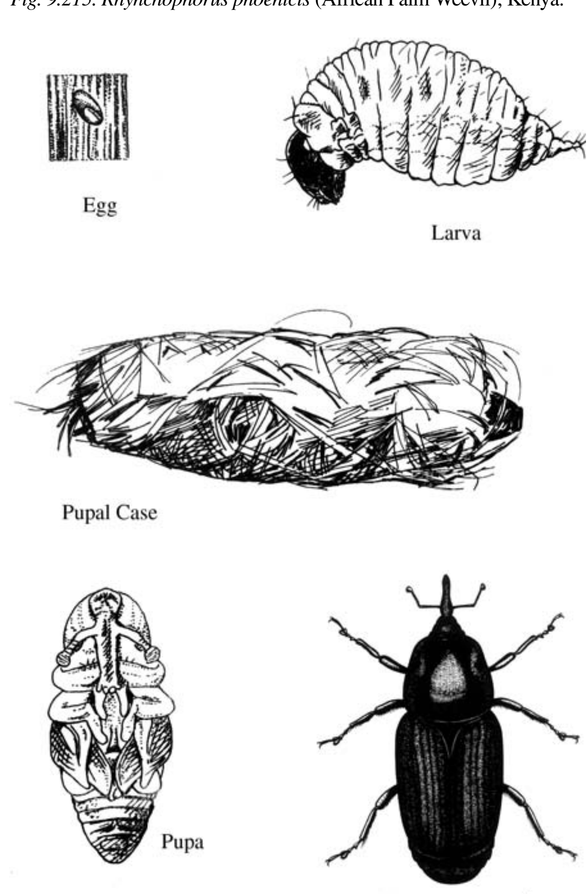
Rhynchophorus phoenicis (F.)

Common name. African Palm Weevil
Family. Curculionidae
Hosts (main). Coconut and oil palm.
(alternative). Date, sago, and other species of Palmae.
Damage. The larvae bore in the crown and feed on the shoot and young leaves, sometimes destroying the growing point, and killing the palm. Leaves turn chlorotic and die. The trunk eventually becomes tunnelled and may break during a storm.
Pest status. A serious pest of palms in tropical Africa.



Life history. For details see *R. ferrugineus*.
The adult is a large species, measuring some 40–55 mm in length, reddish-brown in colour, with two reddish bands on the thorax.
Distribution. This species is confined to tropical Africa, and has been recorded from Ivory Coast, Sierra Leone, Nigeria, Angola, Ghana, Zaïre, and E. Africa.
There are actually many different species of *Rhynchophorus* to be found, many in S.E. Asia and Africa, and many attacking species of Palmae, so field identifications can only be tentative (Wattanapongsiri, 1966).
Control. See under *R. palmarum*.

Fig. 9.215. Rhynchophorus phoenicis (African Palm Weevil); Kenya.



Scyphophorus interstitialis Gyll.
(= *S. acupunctatus* Gyll.)

Common name. Sisal Weevil
Family. Curculionidae
Hosts (main). Sisal
(alternative). Mauritius hemp (*Furcraea gigantea*), and other Agavaceae.
Damage. The larvae tunnel into the bole of the spike in nurseries, and in field sisal grey patches occur on the undersides of the lower leaves, and the plant eventually dies. In a severe attack there may be up to 60% loss of plants in nurseries. Adult damage consists of groups of feeding punctures on the young leaves.
Pest status. This can be a serious pest of sisal in nurseries, and newly planted field sisal.
Life history. Eggs are laid 2–6 at a time in mushy tissue of the sisal plant; each female lays 25–50 eggs. Sometimes the adult will eat out a small cavity in the spike so that local rotting occurs, making a suitable oviposition site. Hatching requires 3–5 days.

There are five larval instars, and the fully developed larva is about 18 mm long, with a head capsule breadth of 4 mm. The body is soft, crinkled, and legless. The larval period is 21–53 days.

For pupation the larva makes a rough cocoon out of pieces of fibre and leaf debris cemented together. The larva remains inside the cocoon for a few days before pupating, passing first through a prepupal stage of 3–10 days. The pupal stage lasts for 7–23 days, typically 12–16.

The adults are small, dull black weevils, varying in length (9–15 mm). The adults tend to remain in the area of their origin and generally dispersal is slow. They are long-lived, and have been kept in captivity for ten months.

The total life-cycle takes 50–90 days; and there may be four or five generations per year.
Distribution. Kenya, Tanzania, Sumatra, Java, Hawaii, Mexico, southern USA (Arizona, Texas, California, and Colorado), W. Indies, and northern S. America (Colombia, and Venezuela) (CIE map no. A66).
Control. The rotting boles should be treated with dieldrin. Adults feeding at the base of the spike can be killed with aldrin, and this insecticide should also be used to protect the young field sisal.

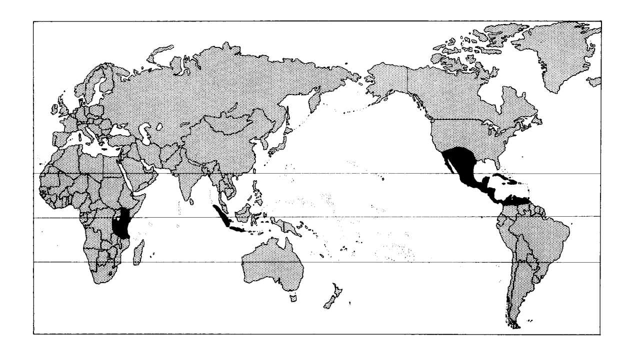
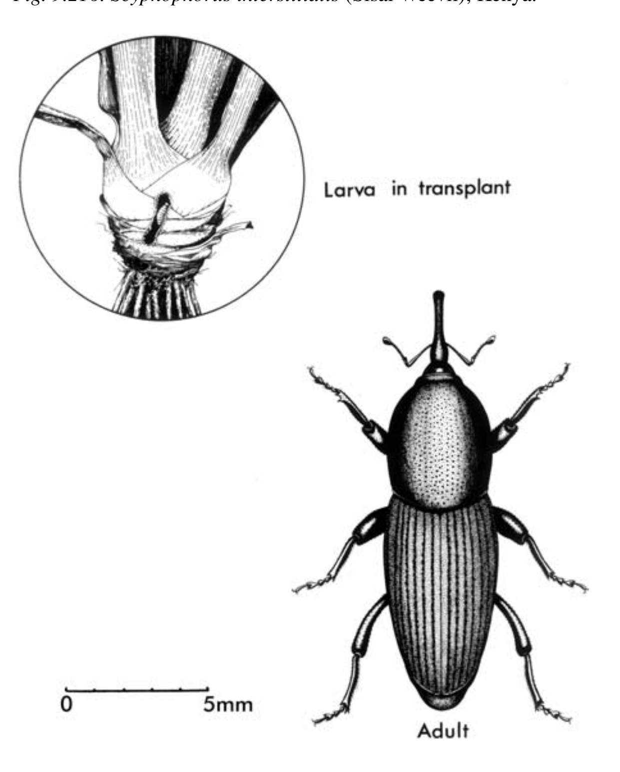


Fig. 9.216. Scyphophorus interstitialis (Sisal Weevil); Kenya.



Sitophilus spp.
(*S. oryzae* (L.))
(*S. zeamais* (Motsch.)

Common name. Rice and Maize Weevils
Family. Curculionidae
Hosts (main). Rice and maize grains in store and in the field.
(alternative). Other stored grains and foodstuffs.
Damage. Larvae develop inside the grains, which become hollowed out.
Pest status. These are very serious primary pests of all stored grains in the warmer parts of the world. On maize, infestations usually start in the field and are later carried into the stores; adults are winged and fly readily.
Life history. Eggs are deposited inside the grains, in small holes chewed by the female; each female may lay 300–400 eggs over a period of several weeks. The larvae remain inside the grains and pupate when they reach a body length of about 4 mm. The adults emerge through the characteristic small circular holes in the grains and are active insects, flying readily and often infesting ripe crops in the field. They are small dark weevils, about 3.0–4.0 mm in length, often with a shiny appearance, and many specimens have four, more or less clearly defined, large reddish patches (spots) on the elytra, which distinguish them from the more temperate *S. granarius*, as well as slightly different sculpturing. These two species are extremely difficult to separate, and usually reliance is placed on male genitalia. For most practical purposes they may be conveniently considered together. Adults generally survive for up to five months.

The life-cycle takes 5–8 weeks, according to temperature, and in warmer regions breeding is continuous, with 6–8 generations per year. Development ceases below 17°C; optimum conditions are temperatures of 27–31°C and humidities above 60% RH.
Distribution. These two species are essentially tropical in distribution, but they do survive and thrive in temperate regions (although only inside grain stores) and in cooler regions they may die over the winter period. Their distributions are generally worldwide throughout the warmer parts of the world, but more abundant in the actual tropics.
Control. For control measures see the recommendations for stored produce beetles, on page 291.
Control. Infested buildings should be thoroughly cleaned and sprayed with BHC or malathion, and any parts of the building which cannot be reached with sprays should be fumigated with the use of DDT/
γ-BHC smoke generators. Infested grain can be mixed with malathion w.p. which is generally successful in achieving control., of pisimiphos-methyl, fenitrothion.

Fumigation of infested grain with methyl bromide, or an ethylene dichloride and carbon tetrachloride mixture is effective but should only be carried out by approved operators because of the toxicity hazards.

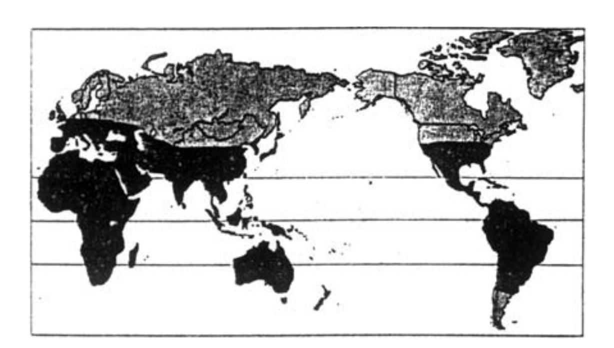
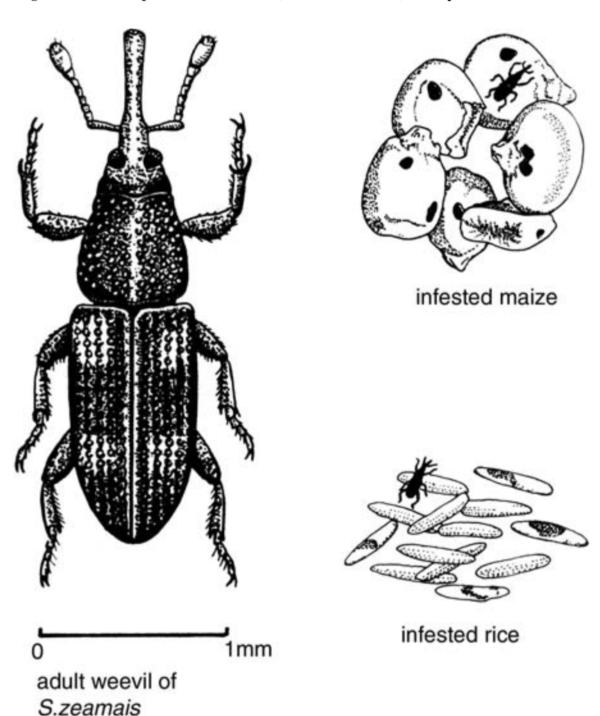


Fig. 9.217. Sitophilus zeamais (Maize Weevil) Kenya.



Sternochetus mangiferae (F.)
(= *Cryptorynchus mangiferae* F.)
(= *Acryptorynchus mangiferae* F.)

Common name. Mango Seed Weevil (Mango Stone Weevil)
Family. Curculionidae
Hosts (main). Mango
(alternative). None recorded.
Damage. There are no external symptoms of attack by this pest. Infested fruits usually fall.
Pest status. The effect of the weevil on yield appears in most years to be quite small. On certain varieties of mango many seeds may be destroyed without the edible part of the fruit being affected.
Life history. The female weevil makes small cuts in the skin of young fruits and inserts a single egg through each cut. The cut normally heals over completely and becomes invisible to the unaided eye.

The larva is a white, legless grub with a brown head. On hatching from the egg it bores through the pulp of the fruit and into the developing seed where it feeds until mature.

Pupation takes place in the seed within the stone of the fruit.

Adult is dark brown with paler patches, some 6–9 mm long. It is a small, stout weevil with a reduced head, and the body covered with scales.

The total life-cycle takes 40–50 days.
Distribution. Africa (Gabon, E. and S. Africa, Madagascar, Mauritius); Pakistan, India, Bangladesh, Sri Lanka, Burma, Malaya, S. Vietnam, Philippines, E. Australia, New Caledonia, and Hawaii (CIE map no. A 180).

A closely related species *S. frigidus* F. occurs in S.E. Asia, but it inhabits the pulp of the fruit and not the seed, hence its name of Mango Weevil. And *S. goniocnemus* is the Mango Twig Borer whose larvae bore the twigs and shoots of mango in Indonesia.
Control. All fallen fruits should be collected and destroyed twice a week. Before planting a mango stone the husk should be cut off to avoid damaging the embryo; if the weevil larva is feeding upon the cotyledons it should be removed, and the seed planted immediately.

Chemical control measures have not proved to be practical against this pest.

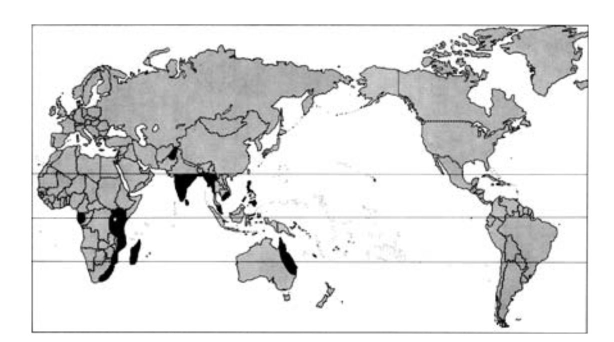
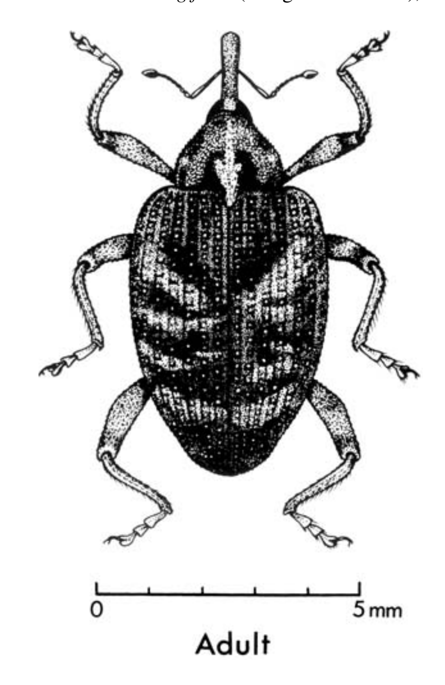


Fig. 9.218. Sternochetus mangiferae (Mango Seed Weevil); Kenya.



Systates spp.

Common name. Systates Weevils
Family. Curculionidae
Hosts (main). *Citrus* and coffee species.
(alternative). Similar leaf damage is seen on a wide range of cultivated and wild plants.
Damage. The edges of attacked leaves have characteristic fjord-like indentations, where the adult weevils have eaten away the lamina.
Pest status. A minor pest of all cultivated *Citrus* and coffee species. Young plants are particularly liable to be attacked and often receive a severe setback.

Several closely related species of *Systates* are equally important as pests.

Life history. Egg, larval and pupal stages have not been recorded from either *Citrus* or coffee; they presumably all occur in the soil.

The adult is a black weevil about 12 mm long with a swollen, rounded abdomen, and long, thin, elbowed antennae. It cannot fly, and is rarely seen during the daytime. At night it feeds on the edges of leaves producing the characteristic feeding damage. Daylight hours are usually spent in the mulch or loose soil near the *Citrus* or coffee trees.
Distribution. E. Africa, Ethiopia
Control. A persistent contact or stomach-acting insecticide must be used both as a foliar spray and on the mulch. The usual insecticides recommended are DDT and dieldrin. For *Citrus* control measures are only required on nursery stock and trees in the first year or two after transplanting.

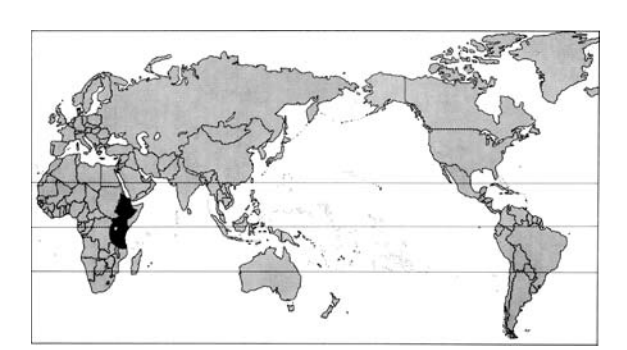
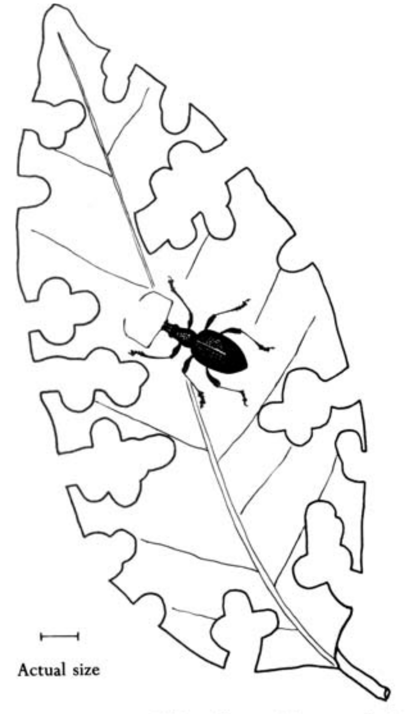


Fig. 9.219. Systates sp. on Citrus Leaf; Kenya.



Hypothenemus hampei (Ferr.)
(= *Stephanoderes hampei* Ferr.)

Common name. Coffee Berry Borer
Family. Scolytidae
Hosts (main). *Coffea* spp.
(alternative). Various Rubiaceae and Leguminoseae, including *Phaseolusd* and *Vigna*, and *Hibiscus* spp.
Damage. One or more round holes can be seen near the apex of large green or ripe berries. The damaged beans, which have a distinctive blue-green staining, contain up to 20 larvae of different sizes.
Pest status. A serious pest of *robusta* and low-altitude *arabica* coffee in many countries.
Life history. Eggs are laid in batches of 8–12 in chambers cut in the hardened maturing coffee bean. Each female lays 30–60 eggs over a period of 3–7 weeks. The eggs hatch in 8–9 days.

The larvae are legless, white with brown heads. They feed by tunnelling in the tissues of the beans. The male larva develops through two instars in 15 days, and the female through three instars in 19 days.

The naked pupal stage is passed in 7–8 days in the larval galleries.

The adult female beetle is about 2.5 mm long, and the male about 1.6 mm. Females are more numerous (sex ratio about 10:1) and fly from tree to tree to oviposit. The males are flightless and remain in the berry, fertilizing females of the same brood.

Infestations are carried over between peaks of fruiting by breeding in over-ripe berries left on the tree or fallen to the ground.
Distribution. Recorded from tropical Africa from W. through to E., Sri Lanka, S.E. Asia, Indonesia, Papua New Guinea, New Caledonia, Caroline, Society and Mariana Isles, C. and S. America (Brazil, Colombia, and Surinam) (CIE map no. A170). Generally spreading in S. America.
Control. Heavy shade, from either shade trees or inadequately pruned coffee, causes conditions unsuitable for the natural enemies of the borer and should be removed. All over-ripe or dried berries should be removed and destroyed. Old crop remains should be stripped completely. These cultural measures, efficiently applied, should be sufficient to control Berry Borer. Carbosulfan, chlorpyriphos, and endosulfan as foliar sprays should only be regarded as a supplement to the cultural measures.

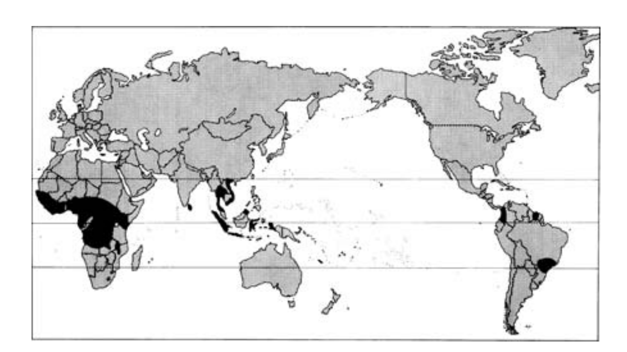
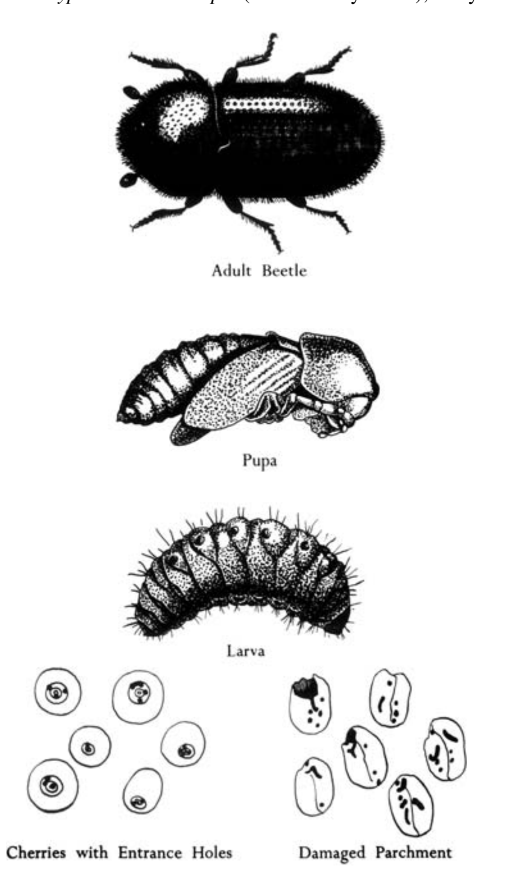


Fig. 9.220. Hypothenemus hampei (Coffee Berry Borer); Kenya.



Bark and ambrosia beetles (Coleoptera; Scolytidae)

These beetles constitute the subfamilies Scolytinae and Platypodicae of the family Scolytidae (although some authorities regard them all as Curculionidae, *sensu lato*). Because of their basic biological differences it is preferable to regard them here as forming a separate family – the Scolytidae.

The adults are small, dark-coloured beetles, cylindrical in shape, with a deflexed head adapted for burrowing in wood and other plant tissues. In terms of burrowing beetles they are rather unusual in that it is the adults who tunnel in the trees and not the larvae. The adults burrow under the bark into sapwood (generally) to make breeding galleries; each gallery being tunnelled by one female. Some species are monogamous (*Scolytus*), others bigamous (*Ips*), and some entirely polygamous (*Xyleborus*) (termed spanandrous) and have a sex ratio of 1:10–50. The male is often smaller than the female, short-lived, flightless, and does not leave the breeding gallery; males are produced from unfertilized eggs and thus are haploid. The adult beetle finds a suitable host tree (or plant) and tunnels under the bark and builds an extensive breeding gallery and inoculates the tunnel lining of frass and faeces with a special fungus (ambrosia fungus). The fungus mycelium spreads over the tunnel walls and is used as food both by the maturing female and the developing larvae. The structure of the tunnel varies with the different genera (and species) of beetle concerned. The female beetle in many species has special body cavities (called mycangia) in which fungal spores or conidia of the 'ambrosia' fungus are carried and kept alive. Some of these fungi belong to the genus *Ambrosiella*. In some species the mycangia are cavities behind the mandibles, in others thoracic tubes, others carry the fungus in the crop.

The different feeding life-styles can be summarized into five basic types (see Beaver, 1977), as follows:

(1) phloeophagy – feeding on the phloem/cambium layer; a very common type, mostly associated with trees in temperate regions.
(2) herbiphagy – feeding on the tissues of soft herbs and woody twigs; an uncommon type; e.g. *Hylastinus*, the Clover Root Borer.
(3) xylophagy – these are the true wood feeders and are quite rare.
(4) spermophagy – feeding on fruits and seeds, and sometimes also leaf-stalks in the tropics; a rare type confined mostly to the tropics; e.g. *Hypothenemus hampei* (Coffee Berry Borer) and *Hypothenemus* spp.; also *Coccotrypes*, the Date Stone Borer.
(5) xylomycetophagy – these species feed on the ambrosia fungus cultivated within a breeding gallery tunnel system either in wood (under the bark) or twigs; a very common type, most abundant in the tropics but quite plentiful in warmer temperate regions; e.g. *Scolytus* and *Xyleborus*.

It is thought that the ambrosia feeders are scarce in the cool temperate regions because the fungus finds conditions too cool for proper development.

Bark beetles are characterized by having very effective dispersal and host-finding mechanisms. They usually have to find a new host for each generation, as most hosts do not survive long enough for more than one generation to develop. Most species attack trees, and most of these seem to prefer sickly or dying trees; very few species attack healthy trees, although some of the twigborers apparently attack healthy twigs, and they also attack and destroy stressed tree seedlings (*Xylosandrus* spp.). Most species are host-selective as to species, and size-selective, usually only attacking trees of a particular size range. Some species are basically forestry pests and prefer newly felled timber as hosts. The group is actually of more importance as forestry pests than as agricultural pests, and the most heavily attacked group of trees are the gymnosperms. Flight activity is controlled by light, temperature and wind; on emergence the females are photopositive, but this later disappears. Distances of dispersal are quite prodigious, being generally 1–30 km per day for several days. Usually a large number of individuals attack the same tree simultaneously; aggregation pheromones are used to facilitate this, but not for most spanandrous species apparently.

The ambrosia beetles all exist in an ectosymbiotic relationship with the fungi, the mycelium of which is an efficient extractor of nutrients from the wood surrounding the gallery. Each beetle usually has one specific fungus, but in addition is usually associated with several others, and also some yeasts and bacteria. The fungal development is essential for both larval development and for maturation of the female's ovaries, as she does not feed prior to dispersal. Fungal development is closely controlled by humidity and temperature; it ceases when the moisture level of the wood drops below about 40–50%. As well as transporting ambrosia fungi, some species also carry pathogenic fungi which often cause the death of the tree. Thus some *Xyleborus* transmit pathogenic fungi to cocoa and mango trees in the tropics, and *Scolytus scolytus* and *S. multistriatus* transmit the causal organism of Dutch Elm Disease (*Ceratostomella ulmi*) in Europe.

Bark beetle pests

In this chapter *Scolytus* and *Xyleborus* are looked at in some detail, but other important genera and species include the following:

Blastophagus (= *Tomicus*) spp. – attack pines, spruces, firs; temperate regions.
Coccotrypes dactyliperda F. – (Date Stone Borer) Mediterranean Region.
Conophthorus spp. – (Pine Cone Beetles) USA and Canada.
Dendroctonus spp. – abundant in pine forests; C. America and USA.
Hylastinus obscurus Marsham – (Clover Root Borer) UK, Europe, Canada, USA.

Hylesinus oleiperda F. – (Olive Bark Beetle) Mediterranean Region.
Hypoborus ficus Erichs. – (Fig Bark Beetle) Med.
Hypothenemus hampei (Ferr.) – (Coffee Berry Borer) Africa, S.E. Asia, and now S. America (CIE map no. A.170).
Ips spp. – attack pines, spruces, firs, larch, etc.; northern Europe, Asia, Canada and USA.
Xylosandrus compactus (Eichh.) – (Black Twig Borer) polyphagous; pantropical (CIE map no. A.244); this species attacks healthy trees.
Xylosandrus morigerus (Bldf.) – (Brown Coffee Borer) polyphagous; S.E. Asia (CIE map no. A.292); a primary pest on some plants, secondary on others.

The most abundant genus in the Platypodinae is *Platypus*; these species are mostly tropical in distribution and most prefer as hosts freshly felled timber, and so are of no agricultural importance.

Control of bark beetles

These beetles are difficult to control because of the nature of their infestations, but the most vulnerable phase in their life-history is the attack/dispersal phase of the adults.

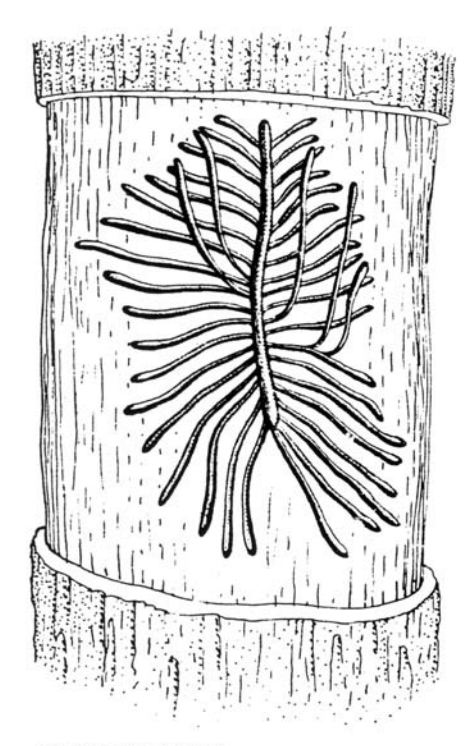
Cultural methods. These consist mainly in trying to keep the trees healthy. Also included is the removal and destruction of infested twigs, branches and trees, and the prompt removal of felled timber. In timber production the drying of felled timber is effective in that the fungus is soon killed. Pruning of crops such as tea and coffee causes some problems in that the pruning sites are often vulnerable to attack both by Scolytidae and sometimes termites.

In some forest situations the trapping of adult beetles is having a definite regulatory effect on pest populations; traps used include sticky traps and ultraviolet light traps, but the most effective are those baited with either aggregation or sex pheromones.

Chemical methods. These fall under several headings. Pheromone traps using aggregation pheromones are quite effective. Use of fungicides to destroy both the ambrosia fungus and the pathogenic fungi can be effective, but is expensive as it requires individual trees being injected using vascular injectors.

Against agricultural pests there are at present, no good standard recommendations. Some success has been achieved using dieldrin as a post-pruning application, or a dieldrin/Bordeaux mixture, or HCH plus heavy sticker solution. Application of tar oil to the tree trunks in the spring will drive out adults from the gallery usually, but application has to be done with great care because of its phytotoxicity to the tree foliage.

Fig. 9.221. Scolytus (Bark Beetle) breeding gallery under the bark on a tree trunk.



Xyleborus spp.

Common name. Shot-hole Borers (Ambrosia Beetles) (Fruit Tree Ambrosia Beetles)
Family. Scolytidae
Hosts (main). Plum, damson, apple, pear, hazelnut, chestnut, tea, coconut, citrus, etc.

(alternative). Many other deciduous trees (oaks, beeches, elms, rowan, holly, etc.).
Damage. The adult beetles tunnel right into the heartwood of trunks and larger branches, and then innoculate the breeding gallery with ambrosia fungus.
Pest status. A localized but quite important pest; but the genus *Xyleborus* occurs worldwide as a large number of important pest species on a wide range of hosts.
Life history. This is a spanandrous (polygamous) species with usually a sex ratio of one male to about 50 females, and the male is physically much smaller than the female. The female makes the breeding gallery by herself, unaccompanied by the male who remains behind in the gallery where he was bred. The main gallery is bored deep into the heartwood as a single tunnel with small lateral egg-chambers where the larvae develop and feed on the ambrosia fungus. Most larvae hatch in May and June, but generally both larvae and adults may be found in the galleries at all times of the year; adults are generally most abundant over the period January to June.

The adults are black in colour with antennae and legs yellow; the male is 2.0–2.5 mm long with short elytra, the female is 3.0–3.5 mm with elytra twice as long as the prothorax, and the male has a generally rounder and less cylindrical body.

There is usually one generation per year.

The various species of *Xyleborus* are similar in appearance and biology.
Distribution. There is a large number of important pest species to be found worldwide on many different trees and woody shrubs, including:
Xyleborus dispar (F.)–(Shot-hole Borer) UK and Europe.
Xyleborus fornicatus (Eichh.) – (Tea Shot-hole Borer) polyphagous; Madagascar, India, S.E. Asia, Papua New Guinea (CIE map no. A.319); a primary pest.
X. ferrugineus (F.)–polyphagous; pantropical (CIE map no. A.277).
X. perforans (Woll.) – (Coconut Shot-hole Borer) polyphagous; pantropical (CIE map no. A.320).
X. saxeseni (Ratz.)–(Fruit Tree Wood Ambrosia Beetle) Europe.

In India there are nine other species of importance as fruit tree pests. In Japan a total of 15 species of *Xyleborus* are agricultural pests including:
X. apicalis Blandford – Apple Ambrosia Beetle.
X. atratus Eichhoff – Mulberry Ambrosia Beetle.
X. semiopacus Eichhoff – Apple Ambrosia Beetle.
X. sobrinus Eichhoff – Citrus Ambrosia Beetle.
Control. For control measures see page 348.

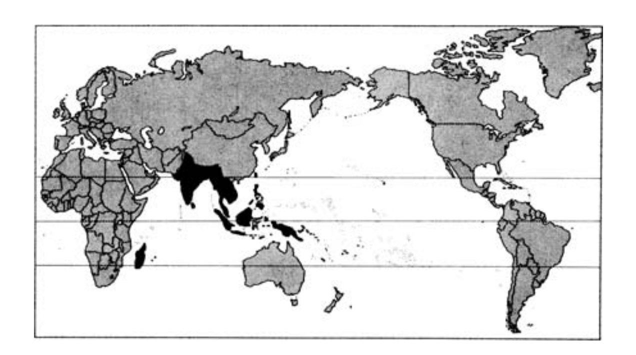
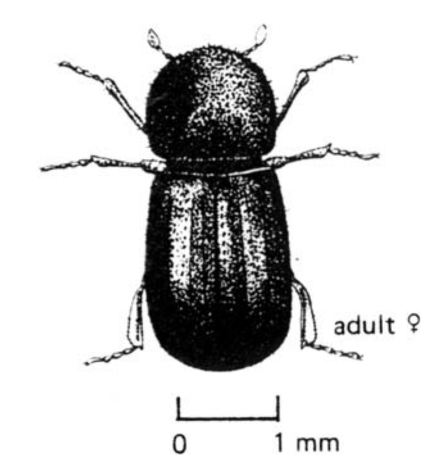


Fig. 9.222. Xyleborus sp. (Shot-hole Borer). Adult ♀.



Xyleborus fornicatus (Eichh.)

Common name. Tea Shot-hole Borer
Family. Scolytidae
Hosts (main). Tea
(alternative). Cocoa, avocado, *Citrus*, castor, rubber, cinchona, etc.
Damage. The adult beetles bore in woody stems generally about 1–2 cm in thickness, and they excavate a system of tunnels which become infected with fungus; this is one of the ambrosia beetles and so the larvae feed on the gallery fungus rather than on the woody tissues of the host. Infestation of stems and branches usually leads to wilting and often the branch breaks at the infestation site; pathogenic fungi are often carried by ambrosia beetles (for example, Dutch Elm Disease in Europe). Fungal attack usually discolours the wood in a very characteristic manner.
Pest status. A primary pest of tea, cocoa, etc., for this species usually attacks healthy trees (many Scolytidae are really secondary pests in that they infest sickly or moribund trees), and because of the fungal infections associated the host tree may be killed.
Life history. The adult beetles bore galleries in the sapwood under the bark of the host and lay the eggs in the galleries. The fungal spores for the ambrosia are carried in special pockets in the beetles' bodies. The larvae feed on the ambrosia fungus in the gallery. Pupation takes place within the gallery.

Male beetles are flightless and usually there is a 1:10 sex ratio, the numerous females being fertilized by the few males in the breeding gallery before dispersal. The females make dispersal flights to new trees during daylight. The adult beetles are small (4–5 mm long), black in colour, cylindrical in shape, and the male usually much smaller than the female, and, as mentioned, flightless.

The life-cycle takes 30–35 days, including the preparation of the gallery for oviposition, and there are some 30–50 offspring per gallery (per female).
Distribution. This species is found from Madagascar, India, S.E. Asia, including Papua New Guinea (CIE map no. A319).

Four other species are of particular importance agriculturally, and the adults are virtually indistinguishable from *X. fornicatus*. They are:
X. perforans (Woll) – Coconut Shot-hole Borer; pantropical (CIE map no. A320)
X. ferrugineus (F.) – many hosts; pantropical (CIE map no. A277)
Xylosandrus compactus (Eichh.) – Black Twig Borer; widespread (CIE map no. A244)
X. morigerus (Bldf.) – Brown Coffee Borer; S.E. Asia (CIE map no. A292).
Control. Cultural methods have met with little success, and in the past sprays of dieldrin with added sticker, sometimes with Bordeaux mixture, have given adequate levels of control.

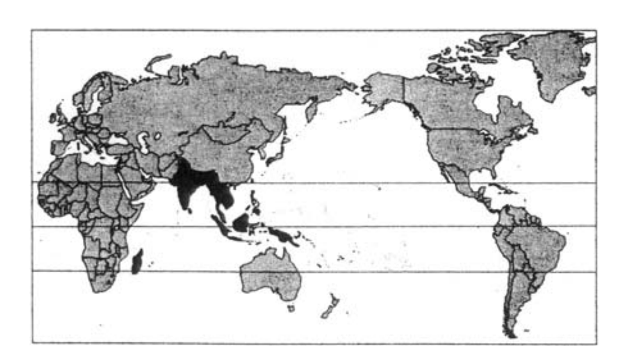
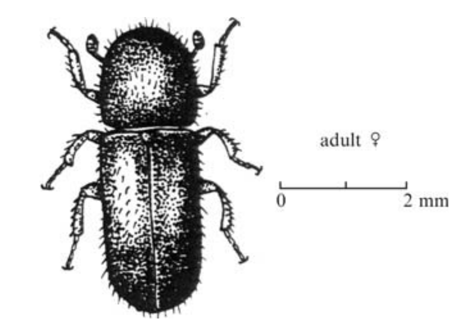


Fig. 9.223. Xyleborus fornicatus (Tea Shot-hole Borer) adult ♀.



Order **DIPTERA**

These are the true flies, with a single pair of membraneous wings, the hindwings modified into halteres. Metamorphosis is complete, the larvae are eruciform and apodous, usually with the head reduced and retracted. Many are crop pests, but more are pests of medical and veterinary importance.

Family **Cecidomyiidae**
(Gall Midges) These are minute delicate flies, with long, moniliform antennae bearing conspicuous whorls of setae; wings with reduced venation. Most of the larvae live in plants and are phytophagous. The phytophagous species may be found in any part of the plant body – roots, stem, leaves, buds, flowers, or fruit, and sometimes galls are formed. Both larvae and adults are often red, orange, or yellow in colour.

For information on gall midges on cultivated plants see the eight volumes by Barnes (1946–59).

Family **Tephritidae** (= Trypetidae)
(Fruit Flies) A well defined group of flies, generally easily recognized, being of moderate size and having mottled wings. The larvae are phytophagous, often living inside fruits, but some are found in flower heads, and inside stems and leaves. The major pest genera are *Dacus* and *Ceratitis*.

For a review of fruit fly ecology see Bateman (1972), also see Drew, Hooper & Bateman (1978).

Family **Agromyzidae**
(Dipterous Leaf Miners) An ill-defined family of small to minute flies whose larvae mine in the leaves and stems of many plants. Some species are virtually host-specific while others attack a wide range of plants. Pupation occurs either in the plant or else in the soil. Some species are endoparasitic on Coccidae. There is an important monograph on this family by Spencer (1973).

Family **Diopsidae**
(Stalk-eyed Flies) This peculiar group of flies is largely confined to Africa and S.E. Asia. The larvae are miners in the leaves of Gramineae or else saprozoic.

For publications of Diopsidae see Shillito (1971, etc.).

Family **Ephydridae**
(Shore Flies) These are black or darkly coloured flies inhabiting damp, marshy places, and are closely related to the Drosophilidae. One genus (*Hydrellia*) is a pest of graminaceous crops, particularly important on paddy rice, and also various pond weeds (*Potamogeton* spp.).

Family **Muscidae**
(House Flies, etc.) A large group of flies of small to medium size usually resembling the House Fly, only some of which are crop pests – these being mainly shoot flies. Most of the Muscidae are medical, veterinary or household pests. Some authorities lump the Anthomyiidae in with the Muscidae as a subfamily.

Family **Anthomyiidae**
(Root Flies; Root Maggots) This is a large family of species, most of which are temperate crop pests but some occur in the tropics. The larvae feed on sown seeds, roots, and in the stems of many crops, especially vegetables and cereals, and some are collectively referred to as root maggots. The Anthomyiidae are separated from the Muscidae by having the anal vein extended right to the wing margin.

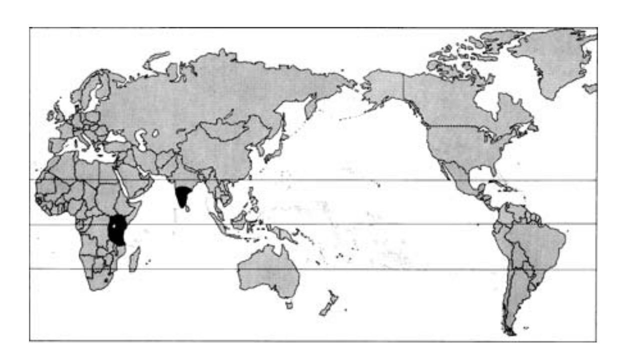
Asphondylia sesami Felt

Common name. Sesame Gall Midge
Family. Cecidomyiidae
Hosts (main). Sesame (*Sesamum indicum*)

(alternative). A wild species, *S. angustifolium*, has been recorded in Uganda.

Damage. Flower buds or capsules are galled by the larvae, and then become twisted and stunted.

Pest status. Usually only a minor pest but occasionally high infestations occur with resulting considerable crop losses.



Life history. Details of the life history are not well known.

Eggs are laid along the veins of the terminal leaves.

The larvae are white, and pupation occurs in the galls on the capsules.

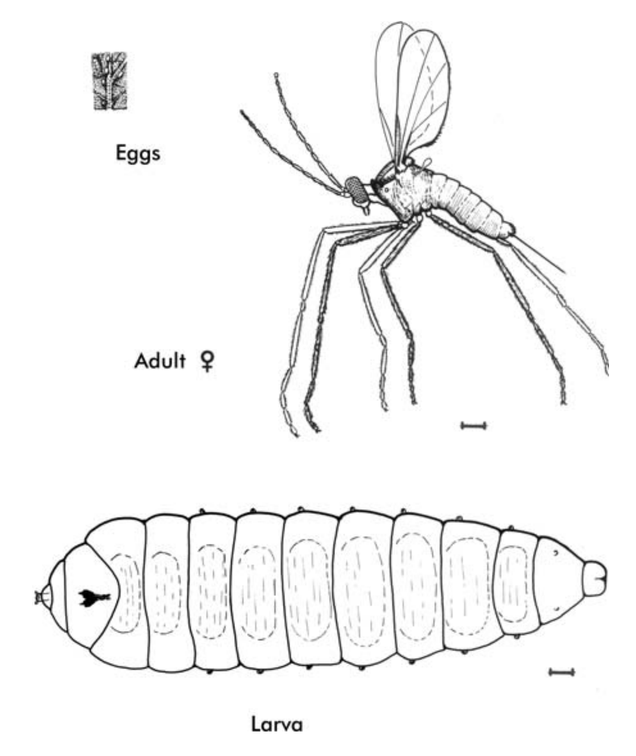
The adult is a large (5 mm long) red-bodied midge.

Generally plants with green capsules appear to be more susceptible to attack by this pest than do ones with black capsules.

Distribution. Only E. Africa and S. India.

Control. No control measures are recorded to date.

Fig. 9.224. Asphondylia sesami (Sesame Gall Midge); Kenya.



Gall midges (Diptera; Cecidomyiidae)

A very large family of minute, fragile flies; they are characterized by having reduced wing venation and long moniliform antennae with whorls of bristles. The larvae are peripneustic, with a reduced head, and usually a distinct sternal spatula. Most species are phytophagous and virtually every species of flowering plant is attacked by at least one species of gall midge. Many midge species are damaging to cultivated plants, and these are reviewed in the eight-volume monograph by Barnes (1946–69), but only a few are pests of any consequence (see below). For the field entomologist most midge species cannot be easily identified (if at all!) as both adults and larvae show striking morphological similarity throughout the family. However, most species are host-specific and larval damage (especially galls) is often distinctive. Thus by knowing the identity of the host plant, and recognizing the type of damage done, it is usually possible to arrive at the identity of the midge concerned. The larvae are often brightly coloured, orange, red or yellow (although most are white), which aids in their recognition.

Larvae show greatly diversified habits, and have been classified as follows:

(1) Zoöphagous species: they mostly prey on Homoptera and on mites; a few prey on other Diptera (both larvae and pupae), and a very few are parasites of aphids and other small Homoptera.

(2) Saprophagous species: found in decaying vegetable matter, fungi and also in the excrement of lepidopterous caterpillars, and dung.

(3) Phytophagous species; these are in turn further subdivided:

(a) plant-feeders making no galls (cereal and grass midges – in flowerheads).

(b) plant gall inquilines: living inside galls induced by some Hymenoptera, Coleoptera or Diptera (Tephritidae, and other Cecidiomyiidae).

(c) true gall-formers (cecidogenous species):

(i) leaf and leaflet semi-galls (*Dasineura* spp. on legumes, rose, violet, etc.).

(ii) leaf galls proper (Longan Gall Midge, etc.).

(iii) shoot and bud galls (Pea Midge; Hawthorn Shoot Midge, etc.).

(iv) seed and fruit galls (Sorghum Midge; Pea Midge; Pear Midge, etc.).

(v) stem galls (*Asphondylia morindae* on *Aporusa chinensis*, etc.).

(vi) root galls.

Gall midges of importance

The three main genera of pest species are as follows; for an indication as to their abundance it may be noted that in the UK there are listed the following number of species for each genus – *Asphondylia* (15 spp.), *Contarinia* (72 spp.), and *Dasineura* (136 spp.). The two groups of plants that are probably the most attacked by gall midges are the Leguminosae and Gramineae. The main pest species of note include, as follows:

Asphondylia sesami Felt – (Sesame Gall Midge) E. Africa and India.
A. websteri Felt – (Alfalfa Gall Midge) USA.
Contarinia johnsoni Felt – (Grape Blossom Midge) USA.
C. mali Barnes – (Apple Blossom Midge) Japan.
C. merceri Barnes – (Cocksfoot/Foxtail Midge) Europe.
C. medicaginis Kieffer – (Lucerne Flower Midge) Europe.
C. nasturtii (Kieffer) – (Swede Midge) Europe.
C. pisi (Winn.) – (Pea Midge) (see page 351).
C. pyrivora (Riley) – (Pear Midge) Europe, USA.
C. humuli (Theobald) – (Hop Strig Midge) Europe.
C. rubicola Kieffer – (Blackberry Flower Midge) Europe.
C. sorghicola (Coq.) – (Sorghum Midge) Africa, Japan, Australia, USA, S. America (CIE map no. A.72).
C. tritici (Kirby) – (Yellow Wheat Blossom Midge) Europe, Asia, Japan (CIE map no. A.182).
C. vaccinii Felt – (Blueberry Tip Midge) USA.
Dasineura affinis (Kieffer) – (Violet Leaf Midge) Europe.
D. brassicae (Winnertz) – (Brassica Pod Midge) Europe.
D. coffeae Barnes – (Coffee Flower Midge) Africa.
D. crataegi (Winnertz) – (Hawthorn Button-top Midge) Europe.
D. leguminicola (Lintner) – (Clover Seed Midge) Europe, Canada, USA.
D. mali (Kieffer) – (Apple Leaf Midge) Europe, Japan.
D. plicatrix (Loew) – (Blackberry Leaf Midge) Europe.
D. pyri (Bouché) – (Pear Leaf Midge) Europe, New Zealand.
D. rhodophaga (Coq) – (Rose Midge) USA.
D. ribicola (Kieffer) – (Gooseberry Leaf Midge) Europe.
D. rosarum (Hardy) – (Rose Leaf Midge) Europe.
D. tetensi (Rub.) – (Black Currant Leaf Midge) Europe.
D. trifolii (Loew) – (Clover Leaf Midge) Europe, USA.
D. viciae (Kietter) – (Vetch Leaf Midge) Europe.
Geromyia pennisiti (Felt) – (Millet Grain Midge) Africa and India.
Haplodiplosis marginata (vR) – (Saddle Gall Midge) on cereals; Europe (page 354).
Japiella medicaginis (Rubs.) – (Lucerne Leaf Midge) Europe, USA.
Mayetiola spp. – (Hessian Fly and Stem Midges) cosmopolitan (page 355).
Mycophila etc. spp. – (Mushroom Midge complex) cosmopolitan.
Neolasioptera murtfeldtiana (Felt) – (Sunflower Seed Midge) USA.
Orseolia oryzae (W-M) – (Rice Stem Gall Midge) Africa, India, S.E. Asia (CIE map no. A.171).
Prodiplosis citrulli Felt – (Cucurbit Midge) USA.
Resseliella occuliperda (R b.) – (Red Bud Borer (of rose)) Europe.
R. soya Monzen – (Soybean Stem Midge) Japan.
R. theobaldi (Barnes) – (Raspberry Cane Midge) Europe.

Rhopalomyia chrysanthemi (Ahl.) – (Chrysanthemum Gall Midge) USA, Japan.
Sitodiplosis mossellana Gehin – (Orange Wheat Blossom Midge) Europe, Asia, N. America (CIE map no. A.183).

Control of gall midges

It is a little difficult to generalize about control of midges owing to the diversity of life-styles; larvae living internally inside plant tissues are difficult to destroy, but the more exposed foliage feeders are vulnerable to both predation and to insecticides.

Cultural control. Varietal resistance is being used quite successfully to combat some species. Other aspects include early or late planting/sowing; stubble and crop residue destruction; crop rotation can also be effective in minimizing damage.

Biological control. Many hymenopterous parasites and several predacious beetles and bugs (Heteroptera) are important natural enemies of many pest species; some pests are regularly kept in check by natural enemies.

Chemical control. Insecticide sprays are used to kill both the delicate little adults in the crop, and the larvae *in situ* on or in the plants. For accurate spray timing a regular infestation/crop monitoring is required, using traps for adults (wind, suction, sticky, etc.), and foliage inspection for larvae and damage symptoms. The insecticides generally used in the past included DDT, endrin, carbaryl, parathion-methyl, and phosalone. Present recommendations include sprays of azinphos-methyl, demeton-*S*-methyl sulphone, demeton-*S*-methyl, dimethoate, fenitrothion and triazophos. Some of the different species require the use of insecticides with different properties. Usually several sprays are required to give adequate temporal coverage.

Contarinia sorghicola (Coq.)

Common name. Sorghum Midge
Family. Cecidomyiidae
Hosts (main). *Sorghum*; cultivated and wild species.
(alternative). *Andropogon gayanus* in Nigeria.
Damage. The larvae feed on the developing seeds, often only one larva per spikelet, but this pest density is sufficient to cause complete loss of grain. In the USA in high infestations there may be 8–10 larvae on the same seed developing to maturity. The grain head is flattened with tiny shrunken seeds, and the orange-coloured larvae or pupae may be seen in the head to confirm the infestation diagnosis.
Pest status. Of common occurrence in Africa; sometimes infestations are serious. Some indigenous varieties of *Sorghum* show resistance to attack by *Contarinia*. In the USA millions of dollars are lost annually as a result of Sorghum Midge attack.
Life history. The eggs are laid while the spikelet is in bloom over a period of some days; some 20–130 eggs being laid per female. Usually the egg is placed near the spikelet tip. After 2–4 days the eggs hatch.

The larvae move down into the ovary and lie there, feeding on the nutrients which would normally nourish the embryo. The fully grown larvae are dark orange. Larval development takes 9–11 days.

The pupae may be either naked or in cocoons according to the weather conditions. Pupation takes 2–6 days if the pupae are naked. Cocooned pupae may hibernate or aestivate.

The adults are stout-bodied, about 2 mm long, and the females have a dark orange abdomen.

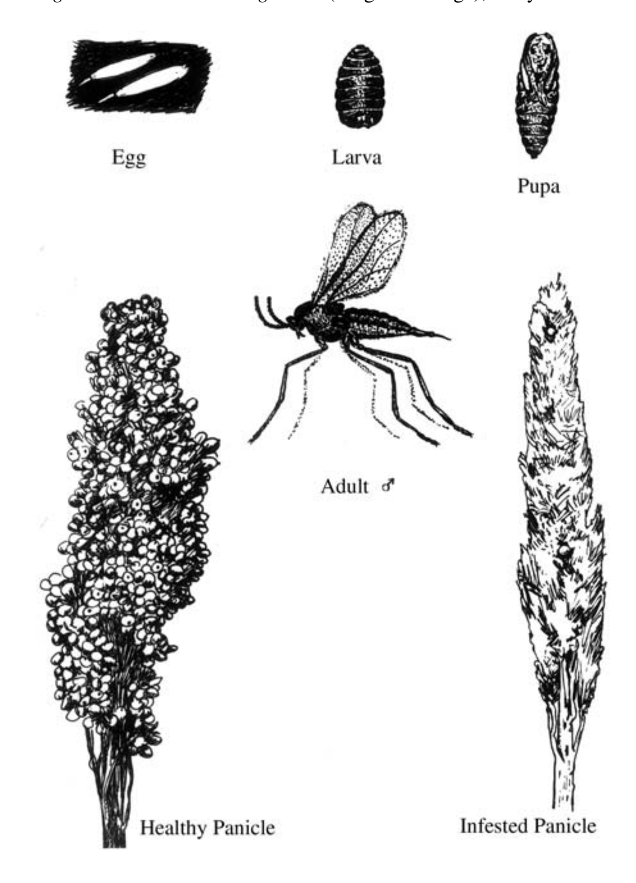
The total life-cycle takes 19–25 days.

Distribution. Scattered throughout the tropics and subtropics; in tropical Africa, from W. through to E.; Java, Australia, southern USA, W. Indies, and S. America (Venezuela) (CIE map no. A72).

Control. Many indigenous African species of *Sorghum* are naturally resistant to Midge attack in that they are less favoured by the female for oviposition. Control measures have generally relied upon the growing of these resistant varieties whenever possible.

Chemical control is difficult in practice; frequent sprays of DDT or carbaryl were fairly effective but chemical residues in the crop become excessive.

Fig. 9.225. Contarinia sorghicola (Sorghum Midge); Kenya



Orseolia spp.
O. oryzae (W.-M.)
O. oryzivora H.&G.

Common name. Rice Stem Gall Midges
Family. Cecidomyiidae
Hosts (main). Rice
(alternative). Wild species of *Oryza*, and grasses.
Damage. The severity of damage is related to the time of attack. The larvae move down between the leaf sheaths until they reach the apical bud or one of the lateral buds. There they lacerate the tissues of the bud and feed until pupation. The feeding causes formation of a gall called a 'silver' or 'onion' shoot.
Pest status. In some areas this is a very serious pest causing crop losses of 30–50% with some regularity and occasionally losses of 100%.
Life history. Fertilized females start egg-laying within a few hours of emergence. They lay 100–300 eggs each. The eggs are elongate, tubular, and white, pink or red in colour. Incubation takes 3–4 days, or more.

The larvae are 1 mm long on hatching, with a pointed anterior end, and a pale colour. They eventually grow to 3 mm long and become red.

Pupation takes place at the base of the gall, and the pupa is 2.0–2.5 mm long and 0.6–0.8 mm broad, pink initially becoming red. Before the adult emerges the pupa makes a hole in the top of the gall with its spines and projects halfway; the skin splits and the adult emerges. Pupation takes 2–8 days.

The adult is a delicate little midge, 3.5 mm long, brown in colour, and with long strong legs.

The whole life-cycle takes 9–26 days on rice, and slightly less on grasses. After one or two generations on grasses the midge generally moves to rice.
Distribution. W. Africa, Sudan, Pakistan, India, Bangladesh, Sri Lanka, S.E. Asia, S. China, Java, and (CIE map no. A171, A.464).
Control. Careful timing of planting can avoid damage by this pest. Once past the tillering stage the plant is not suitable as a host. Considerable build-up of midge populations can occur on grasses near the rice crop.

The success of chemical control is very much dependent on accurate spray-timing to coincide with the emergence of each brood of midges. Several insecticides have been recommended in different countries, with somewhat differing results; these include phosphamidon, parathion, carbaryl, phorate, diazinon, dimethoate, BHC, dieldrin and endrin. Several sprays are necessary during the vulnerable period, that is 20–45 days after transplanting.

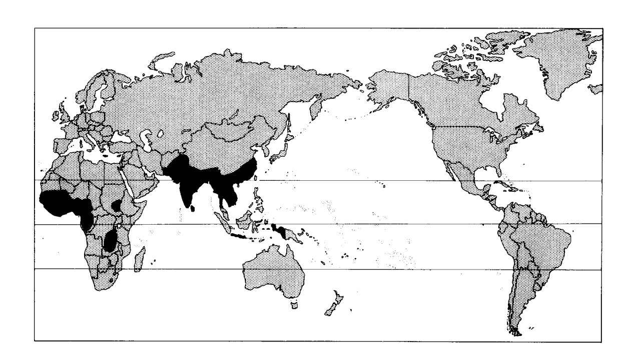
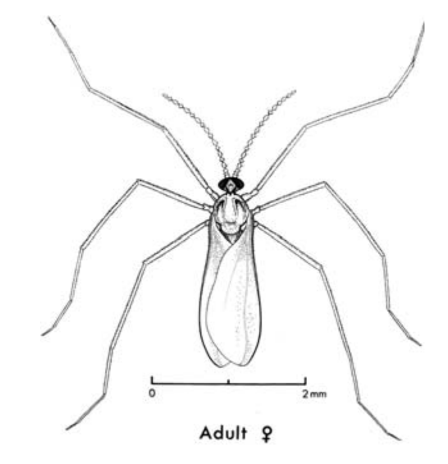


Fig. 9.226. Orseolia sp. (Rice Stem Gall Midge



Ceratitis capitata (Wied.)

Common name. Medfly (Mediterranean Fruit Fly)
Family. Tephritidae
Hosts (main). Fruits of peach, citrus, plum.
(alternative). Many subtropical fruits, including *Ficus*, *Solanum*, cocoa, coffee, mango, guava, etc.
Damage. Eggs are laid inside the fruits and the maggots bore through the fruit while feeding; often associated with fungal and bacterial rots; severely attacked fruits often fall.
Pest status. A very serious pest of many subtropical and deciduous fruits. Many countries have legislation to control accidental introduction of this pest.
Life history. Eggs are laid in groups, under the skin of the fruit, by the female's protrusible ovipositor; each female lays 200–500 eggs; incubation takes 2–3 days.

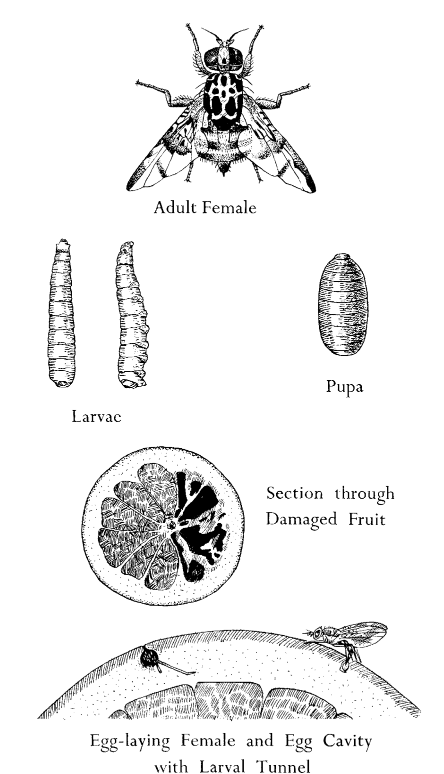
The maggots bore through the pulp of the fruit as they feed and develop; they are white and typically muscoid in appearance. Typically 10–12 maggots per fruit, but up to 100 have been recorded. The three larval instars develop in only 10–14 days under warm conditions.

Pupation takes place in the soil under the tree, in a longish brown puparium; usually the fruit has fallen by the time the maggots leave to pupate. Pupation takes about 14 days.

The adult fly is brightly decorative, with red/blue iridescent eyes and the body blackish with yellow and white markings; length 5–6 mm. Males have characteristic triangular expansions at the end of the antennal arista. Female flies become sexually mature after 4–5 days, and the first eggs are laid about eight days after emergence. Adults require sugary foods, and with food may live for 5–6 months.

The life-cycle takes 30–40 days under warm conditions, and there may be 8–10 generations per year.
Distribution. Essentially a subtropical species; recorded throughout southern Europe, Near East, Africa, S.W. Australia, Hawaii, C. and S. America (CIE map no.A.1). This pest has several times been accidentally introduced into the USA (Florida, California, Texas) but each time the population has been eradicated.
Control. See the following section on control of fruit flies.


Fig. 9.227. Ceratitis capitata (Medfly); Kenya.



Major fruit fly pests

The more important species of fruit flies regarded as economic pests are listed below:

Anastrepha fraterculus (Wied.) – C. and S. America (CIE map no. A.88).

Anastrepha ludens (Lw.)–(Mexican Fruit Fly) C. America (CIE map no. A.89).

Anastrepha mombinpraeoptans Sein – (West Indian Fruit Fly) West Indies, C. and S. America (CIE map no. A.90).

Ceratitis capitata (Wied.) – (Medfly) (see page 357).

Ceratitis catoirii G.-M. – Mauritius and Reunion only (CIE map no. A.226).

Ceratitis coffeae (Bezzi) – (Coffee Fruit Fly) E. Africa.

Ceratitis cosyra (Wlk.) – (Mango Fruit Fly) Africa south of the Sahara.

Ceratitis rosa Karsch – (Natal Fruit Fly) Africa (CIE map no. A.153).

Dacus ciliatus Lw. – (Lesser Pumpkin Fly) Africa and India (CIE map no. A.323).

Dacus cucumis (French) – (Cucumber Fly) Australia.

Dacus cucurbitae Coq. – (Melon Fly) tropical and subtropical Asia, E. Africa, Japan (CIE map no. A.64).

Dacus depressus Shiraki – (Pumpkin Fruit Fly) Japan.

Dacus dorsalis (Hend.) – (Oriental Fruit Fly) tropical and subtropical Asia (CIE map no. A.109).

Dacus musae (Tryon) – (Banana Fruit Fly) Australia (Queensland), Papua New Guinea.

Dacus oleae (Gmel.) – (Olive Fruit Fly) Mediterranean and S. Africa (CIE map no. A.74)

Dacus tryoni (Frogg.) – (Queensland Fruit Fly) E. Australia (CIE map no. A.110).

Dacus tsuneonis Miyake – (Japanese Fruit Fly) China and Japan.

Dacus zonatus (Saund.) – (Peach Fruit Fly) India (CIE map no. A.125).

Euriba zoe (Meig.) – (Chrysanthemum Blotch Miner) Europe.

Paroxyna misella (Lw.) – (Chrysanthemum Stem Fly) Europe.

Pardalaspis cyanescens Bezzi – (Solanum Fruit Fly) Madagascar (CIE map no. A.140).

Pardalaspis quinaria Bezzi – (Rhodesian Fruit Fly) Africa (CIE map no. A.161).

Platyparea poeciloptera (Schrank) – (Asparagus Fly) Continental Europe.

Philophylla heraclei (L.) – (Celery Fly) (see page 361).

Rhacochleana japonica Ito – (Japanese Cherry Fruit Fly) Japan.

Rhagoletis cerasi (L.) – European Cherry Fruit Fly (see page 362).

Rhagoletis cingulata (Lw.) – (Cherry Fruit Fly) N. America (CIE map no. A.159).

Rhagoletis completa Cress. – (Walnut Husk Fly) USA (CIE map no. A.337).

Rhagoletis fausta (O.S.) – (Black Cherry Fruit Fly) USA, Canada (CIE map no. A.160).

Rhagoletis indifferens Curran – (Western Cherry Fruit Fly) USA.

Rhagoletis mendax Curran – (Blueberry Maggot) USA.

Rhagoletis pomonella (Walsh) – (Apple Maggot) N. America (see page 363).

Staurella camelliae Ito – (Camellia Fruit Fly) Japan.

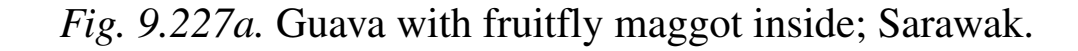
Strauzia longipennis (Wied.) – (Sunflower Maggot) USA.

Toxotrypana curvicauda Gerst. – (Papaya Fruit Fly) USA, India.

Trupanea amoena von Frau. – (Lettuce Fruit Fly) Japan, Europe.

Trypeta trifasciata Shiraki – (Chrysanthemum Fruit Fly) Japan.

Zonosemata electra (Say) – (Pepper (Sweet) Maggot) Canada, USA.


Fig. 9.227a. Guava with fruitfly maggot inside; Sarawak.



Control of Fruit Flies (Tephritidae)

It appears that fruit fly control in most parts of the world now falls into three different categories, as suggested by Drew, Hooper & Bateman (1978).

(1) Control – defined as local procedures aimed at the protection of individual orchards; these procedures usually have little effect on the breeding population of flies in the general area.

(a) Collection and destruction of all infested fruits.

(b) The maggots cannot easily be destroyed for they are inside the fruits and therefore inaccessible, but some success is claimed for the systemic insecticide fenthion.

(c) Use of protein bait sprays, and sex attractants.

(2) Suppression – methods aimed at the control of an entire breeding population, for example in a large valley, part of a State, island, etc., the object being to reduce the level of fruit infestation below the economic threshold. Such wide-scale suppression programmes are appropriate only in areas where the fruit flies are likely to recur each year, and therefore they must normally be repeated in successive seasons.

(a) Protein bait spot sprays – this technique consists of mixing 20 g of protein 'solids' with 10 g malathion per litre of solution, and squirting a 'spot' of this viscous liquid on the crop foliage of about 100 ml in volume. If the 'spots' are dispersed over the foliage in sufficient density, with adequate uniformity over the entire area occupied by the breeding population, then all the winged adults will be killed. Field observations with *D. tryoni* showed that trivial movements of mature females usually daily exceeded 10 m; thus a grid of 'spots' at about 15 m intervals should be adequate to ensure that at least one spot is within the expected daily wandering range of each female fly. For long-term suppression regular application is required, generally weekly sprays at the height of the fly season, and fortnightly at other times, ceasing during the overwintering period.

(3) Eradication – methods aimed at the killing of all individuals in a breeding population; usually undertaken only in areas where the subject species is not endemic and where it has been accidentally introduced. The three methods employed are as follows.

(a) Protein hydrolysate bait sprays – these can be used at short notice and are generally effective if the outbreak is fairly confined, for example the Medfly invasion of Florida in 1956, which involved more than 3000 km^2.

(b) Male annihilation – by using traps baited with female sex pheromones or sex attractants. Generally this is a tool for population monitoring rather than actual population control, but it has been used successfully a few times to eradicate a fly population. Methyl eugenol has a strong attraction for males of various *Dacus* species, and Cu-lure is very effective against *D. cucurbitae* and *D. tryoni*. The sex-lure traps contain suitable insecticides so that entering flies are killed. Generally these traps used together with protein bait sprays are very effective.

(c) Sterile insect release method (SIRM) – following the success of this method against Screw-worm Fly in USA and Curacao, in 1958–9 it was developed for use against fruit flies in the USA and elsewhere. Success was achieved in several cases; *D. dorsalis* was eradicated from Guam in 1963, and *D. cucurbitae* from Rota in 1962–3.

Because of the discontinuous distribution of some species of fruit fly, and their enormous potential as fruit pests, several species are subject to quarantine legislation in different countries or states (USA, Australia), involving restriction of importation of fruit likely to contain the larvae. The main species involved are *Ceratitis capitata, Dacus dorsalis* and *D. tryoni*.

Ceratitis coffeae (Bezzi)
(= *Trirhithrum coffeae* (Bezzi))

Common name. Coffee Fruit Fly
Family. Tephritidae
Hosts (main). Coffee fruit, both *arabica* and *robusta*.
(alternative). Other *Coffea* spp., rarely in *Citrus*, cocoa, mango, *Solanum* spp., and carambola.
Damage. The maggots bore into the mucilage of the ripe berries, (or the fruit.)
Pest status. No real damage is done to *robusta* coffee in E. Africa, with any effect on quality. However, if picking is irregular fruit-fly-induced shedding can be responsible for considerable crop loss.
Life history. Eggs are laid under the skin of the berry, in groups. Hatching usually takes place within two days.

The maggots feed on the fruit mucilage, several larvae can develop to maturity in one fruit. The larval stage usually lasts about 21 days. The mature larvae drop out from the berry into the surface litter under the tree.

Pupation takes place in the litter under the tree, and the pupal period lasts for about ten days.

The adult is a small dark fruit fly with the typical mottled wings shown by this genus.
Distribution. E. Africa and Ethiopia, The closely related *Trirhithrum inscriptum* (Graham) is an important pest of *arabica* coffee in the D.R. Congo.
Control. So far pesticide treatment has not been effective against this pest, and in point of fact dieldrin and trichlorphon appeared to reduce the proportion of larvae parasitized in trials carried out in Uganda.

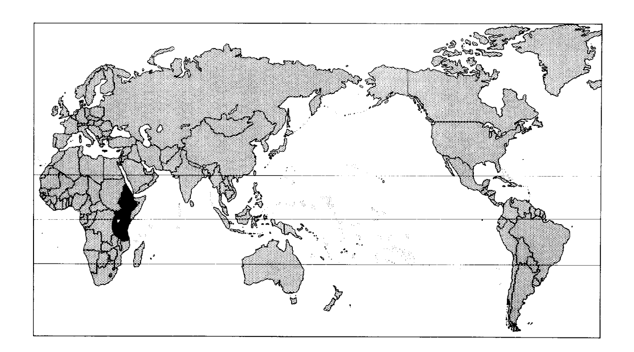
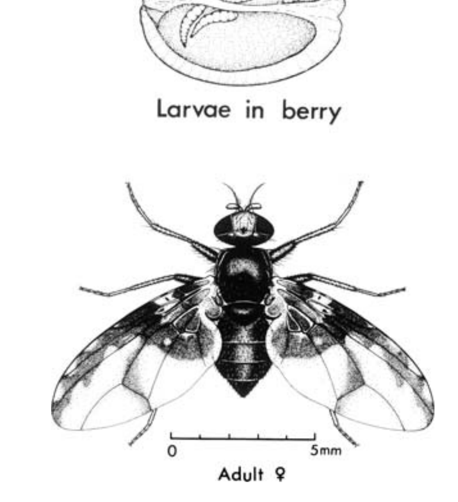


Fig. 9.228. Ceratitis coffeae (Coffee Fruit Fly); Kenya.



Ceratitis cosyra (Wlk.)

(= Pardalaspis cosyra Wlk.)

Common name. Mango Fruit Fly
Family. Tephritidae
Hosts (main). Mango
(alternative). Peach, *Warburgia, Acokanthera*, and *Cordyla* spp.
Damage. The fruits show oviposition punctures with dark stains (rotting) around them. The pulp is heavily mined and the mines contain many small white maggots. The prematurely ripening fruits fall off the tree.
Pest status. Not often a serious pest.
Life history. The biology of this pest is similar to that of *C. capitata*.

The female flies pierce the ripening fruit and insert the eggs into the puncture.

The maggots feed on the pulp, making it worthless as a crop.

Pupation takes place either inside the fruit or underground.

The adult is a small fly, which holds its wings partly extended at rest, and is about 4–5 mm long, and 10 mm wingspan.

There are probably only two generations per year.
Distribution. Africa only, from E. and S. Africa, Zimbabwe, Cameroons, and Zanzibar.
Control. For control measures see *Ceratitis capitata* (p. 359).

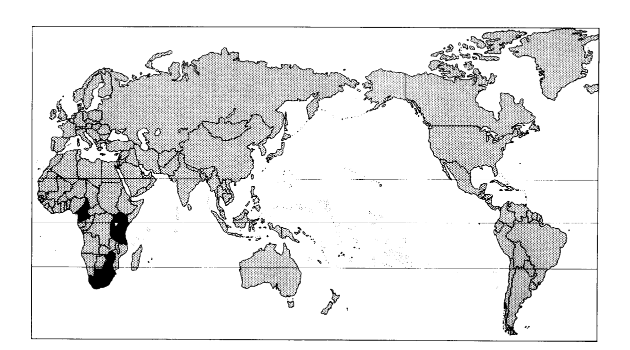
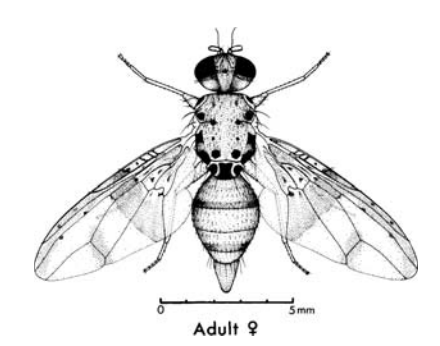


Fig. 9.229. Ceratitis cosyra (Mango Fruit Fly); Kenya.



Ceratitis rosa Karsch
(= *Pterandrus rosa* Karsh)

Common name. Natal Fruit Fly
Family. Tephritidae
Hosts (main). Peach, and *Citrus* spp.
(alternative). Many deciduous and subtropical fruits in S. and E. Africa.
Damage. Fruits show 'stings' caused by the female ovipositor, surrounded by soft dark patches; insect attack is often followed by secondary disease infection. The fruit pulp becomes soft and rotten and contains many small, white maggots. Infested fruits usually fall prematurely.
Pest status. An important pest of fruit in tropical and subtropical Africa, south of the Sahara. This fruit fly is able to breed in harder and greener fruit, and also has more wild hosts than *C. capitata*.
Life history. The eggs are tiny, creamy-white, and elliptical, 0.9 mm long. They are laid in batches in cavities beneath the rind (skin) of the fruit. Several punctures ('stings') may be made without ovipositing and these holes are entry points for fungi and bacteria. Incubation takes 2–4 days.

The maggots are white and legless, tapering to a narrow anterior point; typical of most fly maggots. The three instars take 10–14 days, according to the fruit and the season. The full-grown maggots are 8 mm long, and they leave the fallen fruit to pupate in the soil some 5–20 cm below the surface.

The puparium is elongate and reddish-brown, and the pupal period lasts for 11–12 days.

The adult is a small fly, with a wingspan of about 10–12 mm, with golden bars and markings on otherwise hyaline wings, and 4–6 mm long.

The complete life-cycle takes 21–28 days, and there may be 6–12 generations per year, according to the climate.
Distribution. Only Africa; recorded from Angola, E. Africa, Mauritius, Mozambique, Nigeria, Malawi, Zimbabwe, S. Africa, and Zanzibar (CIE map no. A153).
Control. For control measures see *Ceratitis capitata* (p. 359).

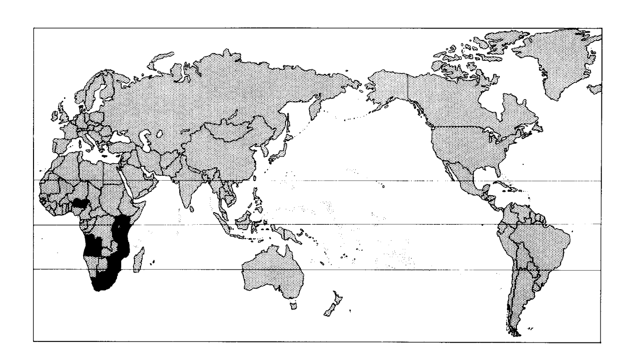
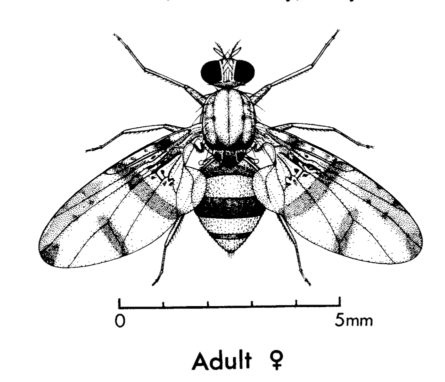


Fig. 9.230. Ceratitis rosa (Natal Fruit Fly); Kenya.



Bactrocera cucurbitae (Coq.)
(= *Dacus cucurbitae* Coq.)
(= *Strumeta cucurbitae* Coq.)

Common name. Melon Fly
Family. Tephritidae
Hosts (main). Melon

(alternative). Other cucurbits, both cultivated and wild; and also recorded from cotton, *Citrus*, sunflower, and lettuce.

Damage. The larvae tunnel in the fruit, contaminating them with frass and providing entry points for fungi and bacteria which cause the fruit to rot. Young fruit can be destroyed in a few days; older fruit show less obvious symptoms, but on cutting open they are found to contain a mass of maggots in the pulp.

Pest status. A very important pest of cucurbits in Africa, India, and Hawaii, rendering these crops quite uncommercial in many areas. The distribution of this pest in India is largely determined by moisture; the population expands when rainfall is adequate and contracts during dry periods.

Life history. Eggs are laid in groups under the skin of young fruit by means of the quite sharp ovipositor of the female.

The larvae are typical dipterous maggots, 10–12 mm long when fully grown, and they bore in the pulp of the fruit.

Pupation takes place in the soil, but occasionally in the fruit, and it takes about ten days. The puparium is elongate, oval, brown, and 6–8 mm long. In drier areas the pupa may enter diapause.

The adult is a large, brown fly, 8–10 mm long, including ovipositor, with a wingspan of 12–15 mm. The eyes and head are dark brown. Wings are hyaline with a dark brown costal stripe extending right up to the tip of the wing; there are a few small infuscate areas in the wings. There are three bright yellow stripes on the dorsum, and the scutellum is yellow. The adults feed on nectar, bird faeces, plant sap, and juices from tissues of damaged or decaying fruit.

The life-cycle takes about 3–4 weeks, and many generations can occur in one year.

Distribution. E. Africa, Mauritius, Pakistan, India, Bangladesh, Sri Lanka, Burma, Malaysia, Indonesia, Thailand, Sarawak, Philippines, Taiwan, China, S. Japan, Ryukyu Isles, Hawaii, and N. Australia (CIE map no. A64).

Several other species of *Dacus* are important fruit pests; *D. oleae* – the Olive Fly; *D. ciliata* – the Lesser Melon Fly; *D. dorsalis* – the Oriental Fruit Fly; *D. tryoni* – the Queensland Fruit Fly; and *D. zonatus* the Peach Fruit Fly of India.

There are some 500 species of *Dacus* but it now seems that many may belong to the genus *Bactrocera* (China, 1998).

Control. Control recommendations are as for *Ceratitis capitata* (p. 359).

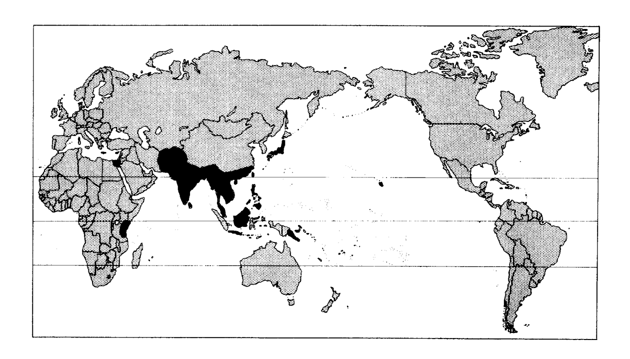
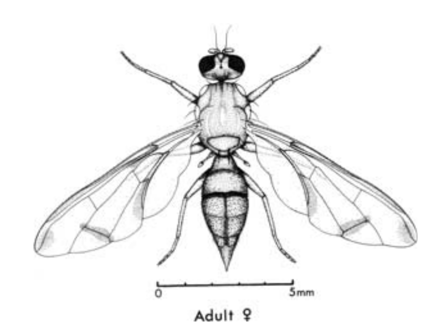


Fig. 9.231. Bactrocera cucurbitae (Melon Fly) Malaysia.



Dacus dorsalis (Hend.)
(= *Dacus ferrugineus***)**
(= *Strumeta dorsalis* Hend.)

Common name. Oriental Fruit Fly
Family. Tephritidae
Hosts (main). Guava, mango, *Citrus*, banana, avocado, papaya, etc.

(alternative). Peach, passion fruit, coffee, melons, pineapple, jackfruit, strawberry; in Hawaii 173 species of plants in 112 genera were recorded.

Damage. Females oviposit through the skin of the fruits and sap may ooze from the punctures. The maggots feed inside the fruits, and their infestation may be associated with fungal and bacterial rots.

Pest status. A serious pest of all fleshy fruits and vegetables in the general S.E. Asia region, and Hawaii.

Life history. The female fly uses her ovipositor to deposit eggs about 5 mm beneath the surface of ripening fruits. The batches of eggs hatch in about two days, and larval development can be as short as seven days before the mature maggots drop out of the fruits to pupate in the soil. Pupal development takes about ten days.

The adult flies are dark brown with bright yellow markings on the thorax, the scutellum is either white or pale yellow, and the hyaline wings have a line of infuscation along the leading edge and down the anal veins. These markings are quite specific, as is shown in the illustrations of Drew, Hooper & Bateman (1978). Adult wingspan is about 15 mm, with body length about 8 mm. The female maturation period is 5–7 days. The entire life-cycle takes only about 25 days in the tropics, where there may be many generations per year, but in cooler regions development is much slower. Temperature limits are 14°C for larval development and 21°C for adult.

Distribution. From Pakistan and India through S.E. Asia to N. Australia, and to China, Taiwan and the Ryukyu Islands and Hawaii (CIE map no. A109).

Control. Bagging of fruits is practised in S.E. Asia to deter ovipositing female flies. Other methods of control include destruction of unmarketable fruits.

Pheromone traps are used for fruit fly monitoring purposes in many orchards. Natural parasitism levels are often quite high, and this pest has, to a great extent, been controlled in Hawaii by the parasite *Opius* (Braconidae).

Chemical control is clearly difficult, and is generally a suppressive procedure aimed at the female flies, usually with a protein bait spray incorporating malathion (or naled), and a chemical attractant.

Some countries have quarantine regulations aimed specifically at this pest.

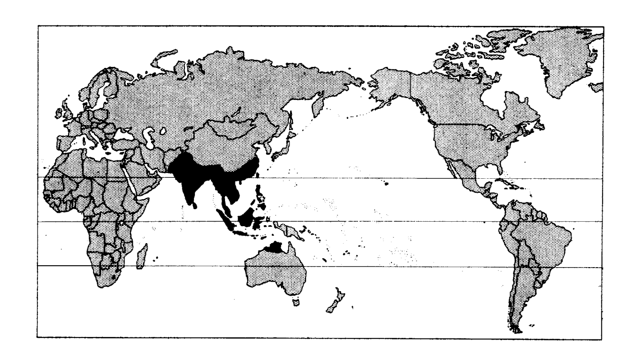
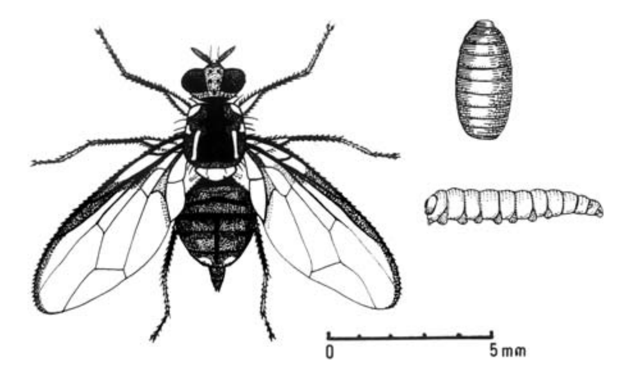


Fig. 9.232. Dacus dorsalis (Oriental Fruit Fly); Malaysia.



Dacus oleae (Gmel.)

Common name. Olive Fruit Fly
Family. Tephritidae
Hosts (main). Olive, both cultivated and wild.
(alternative). None recorded.
Damage. The fruits fall prematurely, and are mottled with a hollowed interior inhabited by a white maggot. Early damage shows as slightly sunken brown necrotic spots. The stone of the fruit is not damaged. Yield can be reduced by as much as 80–90%. The oil from attacked fruit is inferior and has an unpleasant flavour.
Pest status. The most serious pest of olive in the Mediterranean region. 30% crop loss common.
Life history. The female fly lays a single egg on the young olives (about the size of a pea) – if several maggots are found in one fruit then they have come from eggs laid by different females. The egg is deposited under the skin of the fruit; hatching takes 2–3 days.

The maggots are 1–6 mm long, according to their age; larval development takes 10–15 days, according to temperature.

During the summer pupation takes place in the fruit, but the last generation maggots pupate in the soil under the tree, where they overwinter, at a depth of 5–10 cm.

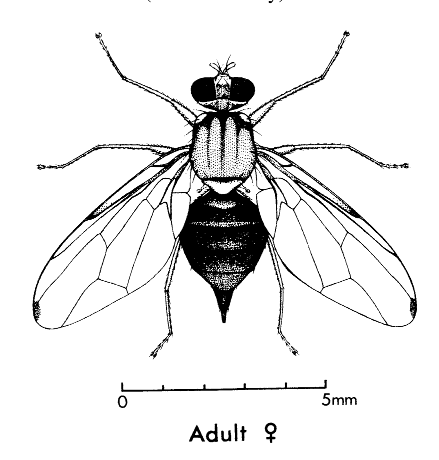
The adult is a small, dark brown fly, about 5 mm long, with hyaline wings having a small dark terminal spot; the female has a prominent ovipositor.

The complete life-cycle in the summer takes about four weeks and there are typically three or four generations per year.
Distribution. The Mediterranean region, Canary Isles, Pakistan, Caucasus, Egypt, Eritrean region of Ethiopia, and S. Africa (CIE map no. A74).
Control. Owing to the site of oviposition being under the skin of the fruit, only systemic or translocatory insecticides will be effective against the larvae. Parathion-methyl is the generally recommended insecticide for use against this pest.

In Greece the practice is to use bait sprays with 4–12% protein, in both aerial and ground application, against the adult flies; most trees receive 2–3 treatments per season; a high level of control is regularly achieved.

Considerable work is in progress on various aspects of biological control for this pest in several European countries.

Fig. 9.233. Dacus oleae (Olive Fruit Fly)



Ophiomyia phaseoli (Tryon)
(= *Melanagromyza phaseoli* (Tryon))

Common name. Bean Fly
Family. Agromyzidae
Hosts (main). Beans of various species, including *Phaseolus, Vicia, Glycine* spp.

(alternative). A wide range of leguminous crops.
Damage. Attacked plants are yellow and stunted; often many are dead. Stems just above soil level are thickened and usually cracked. Attacks on older plants are confined to the leaf petioles.
Pest status. A major pest of beans in Old World tropics.
Life history. The slender, white eggs, 1 mm long, are laid singly in holes made on the upper surface of young leaves, near the petiole end of the leaf.

The larva is a small, white maggot which bores down inside the stem where it feeds just above ground level. The leaves often turn yellow, and the stems develop longitudinal cracks.

Pupation takes place in the stem where the larvae have been feeding. The barrel-shaped pupae are black or dark brown and about 3 mm long.

The adult is a tiny black fly about 2 mm long.

The total life history takes 2–3 weeks.
Distribution. Africa, Pakistan, India, Bangladesh, Sri Lanka, Burma, Malaysia, China, Philippines, Taiwan, Java, Papua New Guinea, West Irian, Australasia, Samoa, Fiji, Caroline and Mariana Isles (CIE map no. A130). Four other species are important pests of grain legumes throughout parts of S.E. Asia.
Control. Successive, overlapping crops of beans should be avoided. Crop residues should be destroyed and volunteer plants removed.

Chemical control can be easily and cheaply achieved by seed dressings of aldrin, dieldrin, or disulphoton, phorate.

Insecticides effective as sprays are monocrotophos, omethoate, oxamyl, triazophos, dimethoate and some synthetic pyrethroids; generally they are applied as two preflowering sprays, two and 12 days after crop emergence.

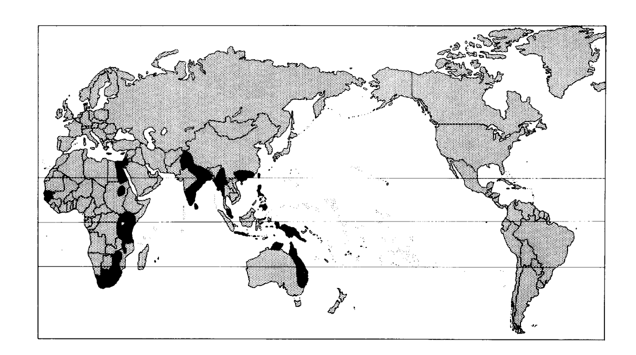
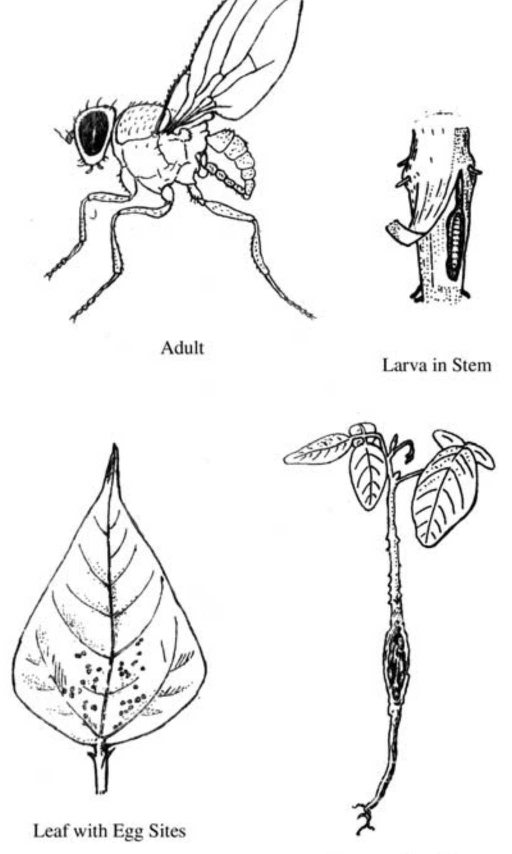


Fig. 9.234. Ophiomyia phaseoli (Bean Fly); Kenya.



Leaf miners (Diptera; Agromyzidae)

A large and widespread group of small flies, most with phytophagous larvae attacking a wide range of plants, most as leaf miners, but some as stem borers, some as borers of leguminous pods, and a few as gall makers. Some species are cosmopolitan, others solely temperate and some restricted to the tropics. The range of host specificity is great, from complete polyphagy to restricted monophagy on a single genus of host plant (such as *Camellia*). About 150 species are regularly associated with cultivated plants, and these were the subject of a monograph by Spencer (1973); the total number of species recorded is about 1800.

The leaf-mining species are characterized by making long winding tunnels (mines) in the leaf lamina; the tunnel appears whitish because of light reflection from the air trapped in the mine: the larval faecal pellets are not very conspicuous as they are deposited at the side of the mine (most leaf-mining caterpillars leave a central black line of pellets). Some species make blotch mines, but this is generally more characteristic of other groups of leaf-mining flies. Pupation takes place usually in the mine at the end of the tunnel, with the two spiracular 'horns' projecting through the leaf epidermis, usually on the underside of the leaf. Some species, however, pupate in the soil, but this is not too common a practice.

Some crops are mined by different species of Agromyzidae in different parts of the world where they are allopatric in distribution, but some flies have overlapping distributions (i.e. sympatric), and some are cosmopolitan. The end-result is that in any one locality some crops are attacked by several very similar leaf miners simultaneously. The identification of Agromyzidae is extremely difficult and many species are really only distinguishable using the male genitalia, but at generic level there are some differences in wing venation and body coloration. The crops most likely to suffer multiple infestation are those belonging to the families Leguminosae, Gramineae, Solanaceae, and Compositae, and also the Cruciferae, Chenopodiaceae and Cucurbitaceae. On a worldwide basis *Beta vulgaris* is attacked by six species, five of which are *Liriomyza*; *Lactuca sativa* has seven species, *Pisum sativum* has 13 species in six different genera, *Hordeum vulgare* has 17 species, and *Triticum aestivum* is attacked by 18 species of Agromyzidae (Spencer, 1973).

The two species dealt with here in detail may be taken as typical of the leaf-mining group of Agromyzidae.

Some important leaf miner (Agromyzidae) pests

Agromyza ambigua Fall. – (Cereal Leaf Miner) Europe, N. America.
Agromyza oryzae (Mun.) – (Rice Leaf Miner) Japan, Java, E. Siberia.
Amauromyza maculosa (Mall.) – (Lettuce Leaf Miner) USA, S. America, Hawaii.
Cerodontha spp. (9) – (Cereal Leaf Miners) only Gramineae; worldwide.
Liriomyza brassicae (Riley) – (Cabbage Leaf Miner) Cruciferae mostly; cosmopolitan.
Liriomyza bryoniae (Kalt.) – (Tomato Leaf Miner) polyphagous; Europe, W. Asia.
Liriomyza cepae (Hering) – (Onion Leaf Miner) Europe (not UK).
Liriomyza chinensis (Kato) – (Onion Leaf Miner) Japan, China, Malaysia.
Liriomyza sativae Blanch.–polyphagous: Cucurbitaceae, Solanaceae, Leguminosae; USA, C. and S. America.
Liriomyza trifolii (Burgess)–((American) Serpentine Leaf Miner) polyphagous; N. and S. America, introduced to UK.
Melanagromyza obtusa Mall.–(Bean Pod Fly) India, S.E. Asia.
Melanagromyza sojae (Zehn.) – (Bean Fly) Africa, S.E. Asia.
Ophiomyia phaseoli (Tryon) – (Bean Fly) Africa, Asia, Australasia (CIE map no. A.130).
Napomyza carotae Sp. – (Carrot Root Miner) Europe (not UK)
Phytobia spp. – (Cambium Borers) in twigs and trunks of many trees (apple, birch, willows, etc.); Holarctic.
Phytomyza horticola Goureau – (Pea Leaf Miner) polyphagous (see page 364).
Phytomyza rufipes Meig. – (Cabbage Leaf Miner) Europe, Canada, USA.
Phytomyza syngensiae (Hardy) – (Chrysanthemum Leaf Miner) polyphagous (see page 367).
Ptochomyza asparagi Hering – (Asparagus Leaf Miner) Europe, China.
Tropicomyia spp. (5) – (Tea Leaf Miners) some polyphagous; Africa, Asia, Japan, Australasia.

Control of leaf miners (Agromyzidae)

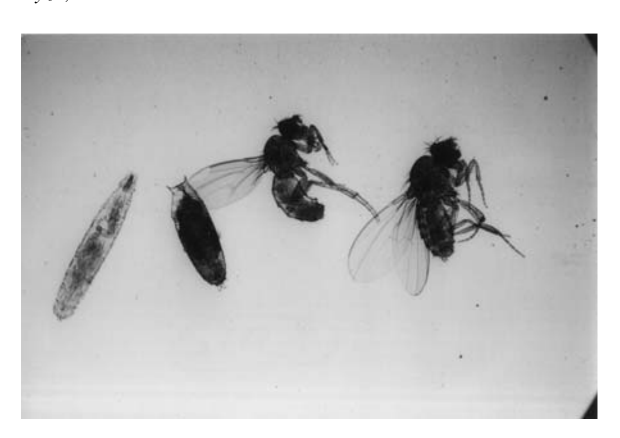
With many species the larval infestation is conspicuous, especially the leaf mines, but actual damage is often slight. The level of natural parasitism is often high and serves to keep the pest population in check; field observations of *Tropicomyia theae* on tea have shown that the level of parasitism is often as high as 70%. For many field crops where the damage consists of leaf mining, it is neither necessary nor really feasible to consider applying control measures.

Bean Fly (*Ophiomyia phaseoli*) is different from most in that it bores in the stems of bean seedlings, and here the usual method of control is to use seed dressings (formerly dieldrin, now phorate and disulfoton) or foliar sprays of dimethoate, permethrin, monocrotophos, omethoate, oxamyl and triazophos, applied twice, two and 12 days after crop emergence.

With glasshouse crops of high value, the most effective control measure is to apply aldicarb granules to the soil 2–4 weeks after planting. The systemic nature of this insecticide both deters adult flies from feeding on the leaves, and causes a reduction in the number of eggs laid, as well as killing the young larvae soon after hatching. An alternative method is to use foliar sprays of γHCH, diazinon, or nicotine, but these

will not kill the pupae. Pirimicarb (used for aphid control) is also effective. It should be noted that chrysanthemums are sensitive to some insecticides so care should be taken when treating this crop in glasshouses.

Fig. 9.234. a Leaf miners, larva, pupa and adults, probably *Phytomyza*; S. China.



Phytomyza horticola Goureau
(= *P. atricornis* Mg.)

Common name. Pea Leaf Miner
Family. Agromyzidae
Hosts (main). Pea, brassicas, lettuce, onion.
(alternative). Flax, tomato, cucurbits; many other crops and wild plants; polyphagous.
Damage. The larvae make irregular linear mines in the leaves, in the mesophyll between the upper and lower epidermis. If many leaves are mined the yield (of peas) may be reduced; in *Brassica* the damage affects saleability: heavily infested leaves shrivel and wither.
Pest status. Widespread and abundant, recorded from many different crops; a pest of importance, but only needs controlling at very high infestation levels.
Life history. The adult flies feed by making small epidermal punctures in the leaves, and some of the feeding sites are used for oviposition, so the eggs are deposited into the leaf tissues. The number of eggs laid per female is recorded as 300–350, some 50 per day. As many as 150 feeding punctures have been counted in one leaf of *Pisum*, but eggs were only found in a few. Egg development takes 2–6 days.

The larva feeds within the leaf, making a long serpentine tunnel that may cross over itself in places; the feeding mine widens as the larva develops. Larval development takes 5–10 days, by which time the larva is 3–4 mm long, and greenish-white in colour. Pupation occurs at the end of the mine, and the brown puparium is clearly visible. The pupal period is from 7–15 days, but may be much longer at low temperatures.

The adult is a small blackish fly, 2–3 mm long, with a pale face, some yellow lateral markings and yellow ‘knees’, and is not a strong flier: first-generation adults are found in May in the UK.

There are 2–4 generations per year in Europe. In the Mediterranean and N. India the period of fly activity is during the winter months.
Distribution. Recorded throughout Europe, Asia, and parts of Africa (CIE map no. A.374; also A.205 as *P. atricornis*), as far north as Iceland.
Control. Many chalcids and ichneumonids are recorded parasitizing this species, and under normal conditions population control is effected by these natural enemies.

For further information on control see page 367.

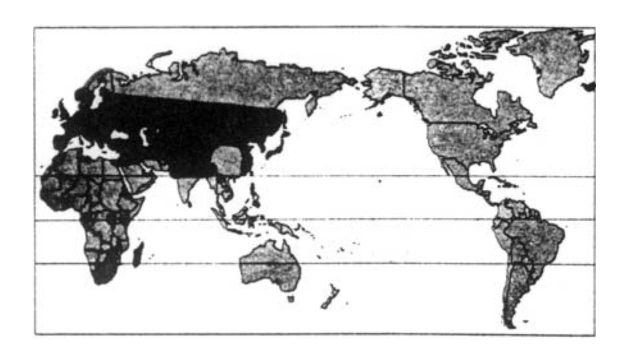
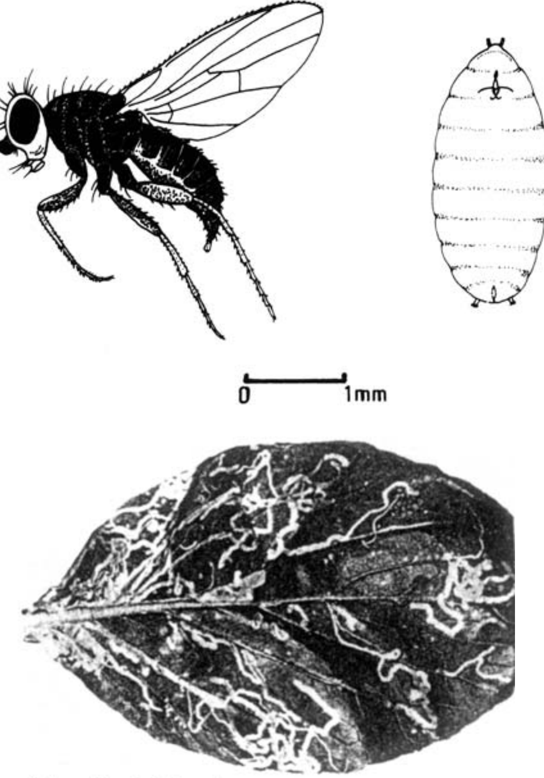


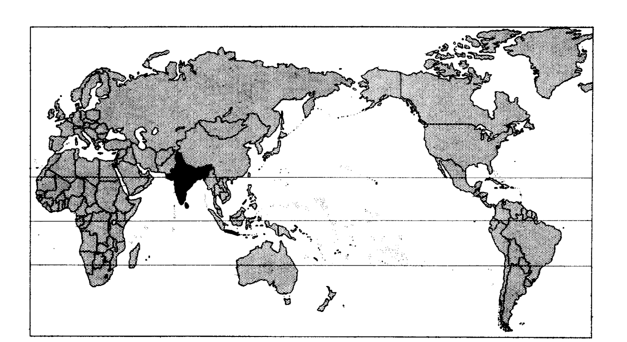
Fig. 9.235. Phytomyza horticola (Pea Leaf Miner); Kenya.



Tropicomyia theae (Cotes)
(=*Melanagromyza theae* Bigot)

Common name. Tea Leaf Miner
Family. Agromyzidae
Hosts (main). Tea
(alternative). None recorded.
Damage. The larvae make tunnel mines in the leaves of the host plant, leading to leaf distortion and sometimes destruction by fungal attack.
Pest status. Of regular occurrence within its distribution range, on tea foliage, but usually only a minor pest.
Life history. Eggs are laid singly underneath the upper epidermis of the leaf; either one or two eggs per leaf. The second and third leaves from the bud seem to be preferred. The larva makes an irregular silvery tunnel mine in the upper part of the leaf. After about 11 days pupation takes place within the end of the mine, with the anterior spiracles projecting through the epidermis; pupation takes about 15 days.

The adult is a small black fly about 3 mm in body length, which resembles many other adult Agromyzidae and is not easily identified.
Distribution. India, Sri Lanka and the Seychelles. Spencer (1973) established this new genus to accommodate a group of tiny leaf-miners occurring widely throughout the Old World tropics and reaching Australia and Japan, on tea and some other plants. Four other species also mine tea leaves; *T. atomella* (Mall.) in India, Sri Lanka, Thailand and Taiwan; *T. flacourtiae* (Seg.) in S., E., and W. Africa, and Madagascar (also in coffee, *Citrus*, cotton, and many wild hosts); *T. polyphyta* (Klein.) in Australia, on many different crops and wild hosts; and *T. styricola* (Sasakawa) in Japan, on several different hosts.
Control. Normally not required; in most places larval and pupal parasitism by parasitic wasps keeps the populations down to a fairly low level. Field observations reveal that levels of parasitism are often as high as 70%.



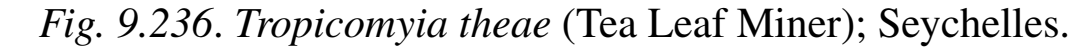


Fig. 9.236. Tropicomyia theae (Tea Leaf Miner); Seychelles.



leaves of tea with larval mines

Diopsis thoracica Westw.

Common name. Stalk-eyed Fly (Stalk-eyed Borer)
Family. Diopsidae
Hosts (main). Rice, and *Sorghum*.
(alternative). Probably occurs on wild grasses also but this is not known for certain.
Damage. The maggot feeds on the central shoot of the young rice plant, causing a typical 'dead-heart'. Later generations of larvae feed on the flower head before it emerges.
Pest status. A serious pest of rice in Swaziland and North Cameroon, and Sierra Leone, but generally this pest is more of academic interest than economic.
Life history. The eggs are 1.7 × 0.4 mm, white, boat-shaped, with a characteristic anterior projection. Each female lays about 20 eggs over a 10-day period. The eggs are laid singly on the upper surface of young rice leaves, usually on the subterminal leaf, fixed to the leaf by cement which prevents their being washed off in heavy rain.

The larva on emergence moves down inside the leaf sheath and feeds on the central shoot above the causing a 'dead heart' meristem. Later larvae feed on the flower head before it emerges. The mature larvae are 18 × 3 mm, white with terminal yellow markings, and with very small heads. Larval development takes 25–33 days.

The pupae are red with brown dorsal bands, fat, and almost triangular in section because of their compression inside the rice stem. The pupal period is 10–12 days.

The adults are typical diopsid flies with characteristic eyes and antennae borne on the ends of long lateral stalks. *D. thoracica* has a red abdomen and two long posterior spines on the thorax.
Distribution. Africa only; from Somalia and E. through Zaïre to Cameroons and W. Africa, down to S. Africa.

There are many species of *Diopsis* in Africa, at least five of which have been associated with rice, and several species in the Oriental region, especially malaysia
Control. The economic importance of this pest is not clearly established.

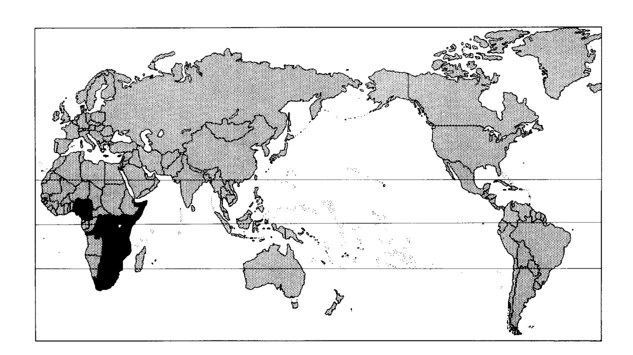
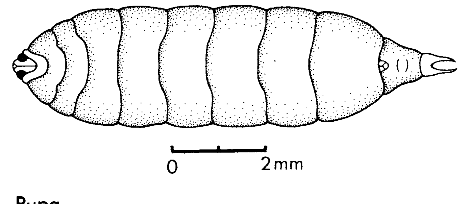
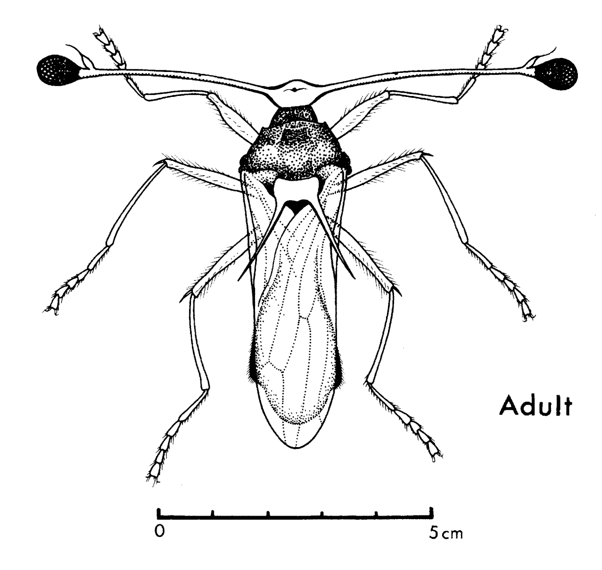


Fig. 9.237. Diopsis thoracica (Stalk-eyed Fly); Kenya.





Hydrellia griseola Fall.

Common name. Cereal Leaf Miner (Rice Whorl Maggot)
Family. Ephydridae
Hosts (main). Wheat, barley, oats.

(alternative). Rice, and many species of grasses and sedges, and some aquatic plants.

Damage. The maggots bore in the leaves, feeding on the mesophyll tissue; the mines are initially linear, later coalescing into a blotch. Damaged leaves shrivel and may die. Most damage is done under moist conditions.

Pest status. A widespread pest of cereals; most damaging on rice in California; occasionally serious on other cereals grown under damp conditions, i.e. where there are summer rains.

Life history. Eggs are laid singly on the leaves; each female laying 50–100 eggs. Hatching takes 3–5 days.

On hatching the maggots immedately bore into the leaf tissues; the feeding tunnel is initially a linear mine but soon coalesces into a blotch (whorl). Larval development under warm conditions takes 7–10 days, but is recorded as being as long as 40 days in northern regions.

Pupation takes place within the mine and the brown puparium is clearly visible; the pupal period is 5–40 days according to temperature.

The adult is a small grey fly with long legs (like a small house fly), with a shining grey frontal lunule; wingspan 2.5–3.2 mm; males are the smaller. Females start egg-laying three days after emergence, and can live for 3–4 months. body length 1.5–2.5 mm

In the warmth of California there are 11 generations per year, but in northern Japan there are usually eight generations.

Distribution. Found throughout Europe (not UK) and temperate Asia, N. Africa, Egypt, Near East, Malaysia, China, Korea, Japan, USA and S. America.

Closely related species include:

Hydrellia philippina Ferino – (Rice Whorl Maggot) Philippines, Japan.
H. sasakii Y.et S. – (Paddy Stem Maggot) Japan.
H. tritici Coq. on wheat in temperate Australia.
Various species of *Notiphila* in China and Japan bore in the roots of rice plants. Species of *Ephydra* are rice pests in S. France, Spain, Egypt, Hungary, and C. Asia.

Other species of *Hydrellia* have larvae that mine the leaves of *Potamogeton*, watercress and other aquatic plants in freshwater habitats.

Control. The usual treatment when control is really necessary has been foliar sprays of dieldrin or heptachlor, which kills both adult flies and the mining maggots.

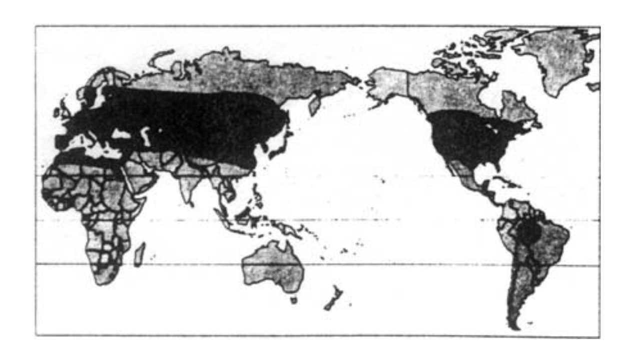
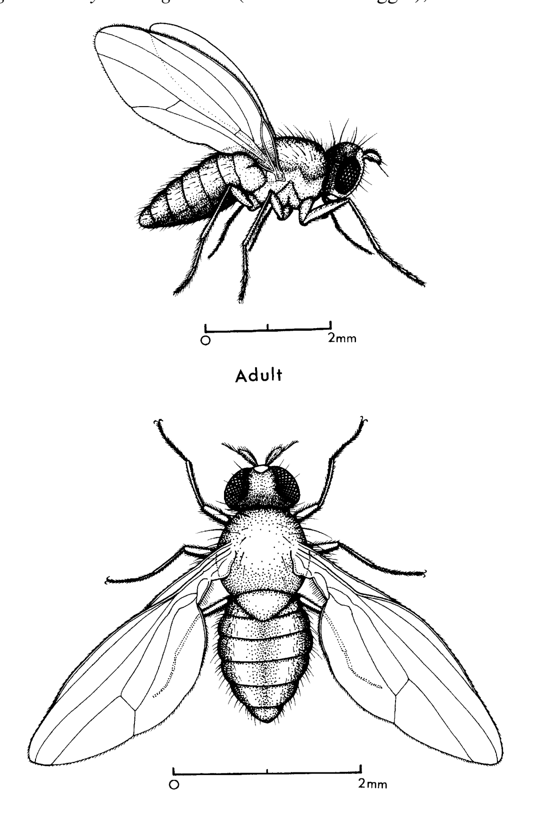


Fig. 9.238. Hydrellia griseola (Rice Whorl Maggot); S. China.



Atherigona oryzae Mall.

Common name. Rice Stem Fly (Corn Seedling Maggot)
Family. Muscidae
Hosts (main). Rice

(alternative). Maize, sorghum, wheat, barley, rye, and various grasses.

Damage. This pest only attacks upland paddy (i.e. non-irrigated rice). The maggots bore into the stem and feed on the basal part of the youngest leaf causing a typical dipterous 'dead-heart'.

Pest status. A pest of upland rice of some importance locally, in various different areas.

Life history. Eggs are laid on the upper and lower surfaces of rice seedling leaves; they are relatively large, being 1.5 mm in length, elongate, and white.

The tiny larvae move down the leaves, pass between the leaf sheath and stem, and bore into the stem of the seedling, at about the level of the growing point. They feed on the developing shoot causing the youngest leaf to die, which then turns brown and withers.

Pupation takes place in the soil, and the larva pupates within a pale brown puparium.

The adult looks like a small grey housefly, about 3 mm long, with a yellow spotted abdomen and yellow legs. The head has a distinctive angular shape with deep-set antennae.

The total life-cycle takes 15–32 days.

Distribution. India, Bangladesh, Sri Lanka, Malaysia, Indonesia, Philippines, China, Japan, Papua New Guinea, West Irian and Australia. (CIE map no. A411).

Atherigona exigua Stein is the Rice Seedling Fly of S.E. Asia, and several other species of *Atherigona* are recorded from rice.

Control. Inundation of nurseries at intervals can be effective, but is not really feasible. Early sowing can be advantageous in some areas.

Seed dressings using aldrin, dieldrin, and endrin, have been quite effective. Cover sprays of parathion and endrin, applied at the first sign of damage, have given good results.

Certain varieties of rice are apparently not attacked by this pest.

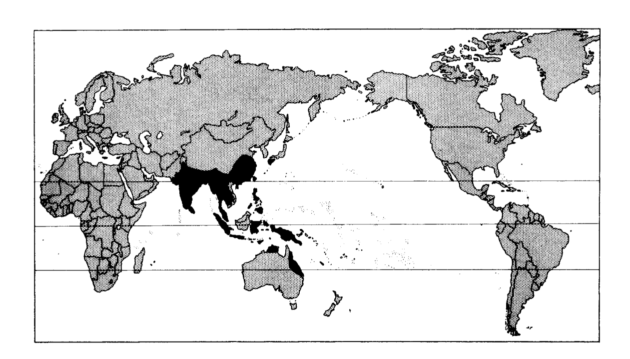
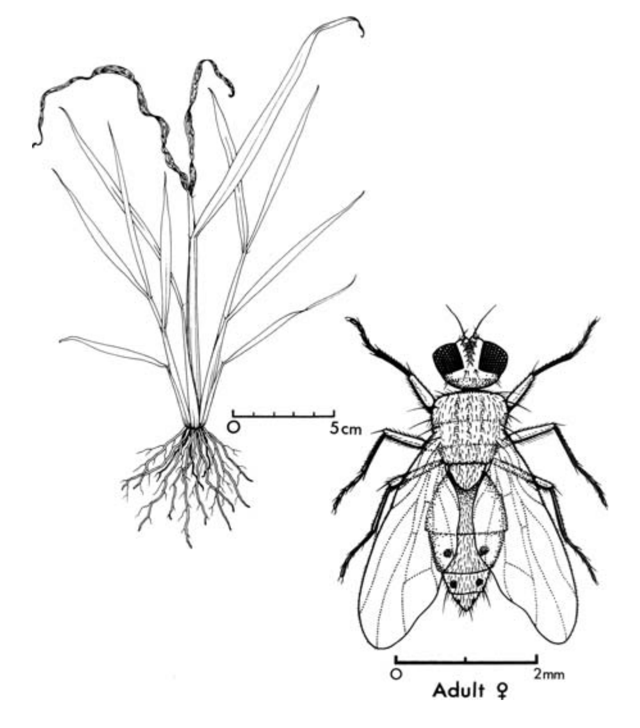


Fig. 9.239. Atherigona oryzae (Rice Stem Fly); S. China.



Atherigona soccata Rond.

Common name. Sorghum Shoot Fly
Family. Muscidae
Hosts (main). *Sorghum* spp.
(alternative). Maize, finger millet, bulrush millet, rice, wheat, and the grasses *Andropogon sorghum, A. s. saccharatum, Cynodon dactylon, Elusine* spp., and *Panicum* spp.
Damage. The maggot feeds on the growing point of the shoot of the seedling causing a typical dipterous 'dead-heart'. Attack usually results in tillering, and in severe attacks the tillers in turn may be attacked. The damage by this fly is indistinguishable from that by other Muscidae, Chloropidae and Oscinellidae.
Pest status. The most serious shoot fly pest of *Sorghum* seedlings in many parts of the Old World tropics, but many other species of shoot flies do occur. Deeming (1971) recorded 50 species of *Atherigona* from cereal crops in N. Nigeria, and described 23 as new species.
Life history. Eggs are laid on the underside of the leaves of seedlings which are 7–8 days old, or on young tillers. Often a single egg is laid per leaf, but up to three have been recorded. The eggs are white, elongate, 0.8 × 0.2 mm, with a raised, flattened, longitudinal ridge. Hatching takes 2–3 days.

The young larvae crawl down inside the sheath and then bore horizontally into the base of the young shoot, killing the growing point and the youngest leaf which eventually turns brown and withers. The third instar larva is white to yellowish, about 10 mm long and 1.3 mm broad, with the anterior spiracle of a rosette type with 8–10 digitations. Larval development takes 7–12 days.

Pupation takes place in the base of the necrotic shoot, or rarely in the soil, and takes about seven days. Under unfavourable conditions the pupae may aestivate.

The adult is rather like a small housefly in appearance, 4–5 mm long. The female has head and thorax pale grey, and abdomen yellowish with paired brown patches; the male is blacker. Under the warmest conditions the life-cycle only takes 17 days, but this may be 21 days in cooler weather.
Distribution. Old World tropics from the Canary Isles to Central Asia; W., E. and S. Africa, Sudan, Ethiopia, Zaïre, Madagascar, Mauritius; and from N. Italy to India, Burma, and Thailand (CIE map no. A311).
Control. See following section on the control of cereal shoot flies.

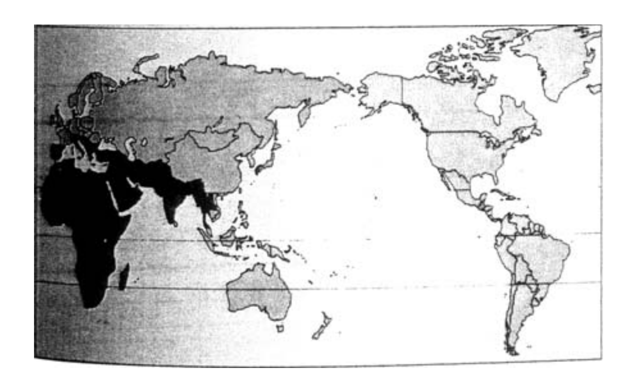
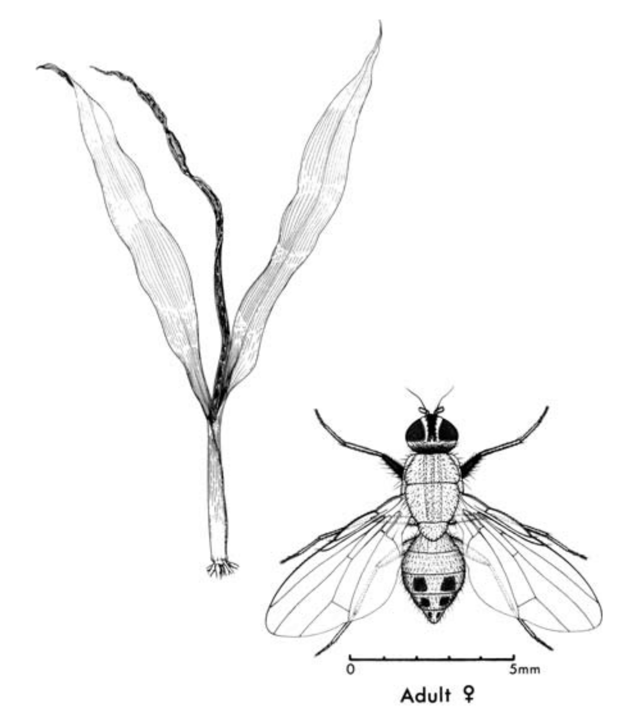


Fig. 9.240. Atherigona soccata (Sorghum Shoot Fly); Kenya.



Control of Cereal Shoot Flies (Muscidae & Anthomyiidae)

The eggs are laid either on the young leaves of the seedling or on the soil at the plant base, and the first instar maggots crawl inside the seedling leaf-sheath and bore horizontally into the shoot, killing the growing point and causing the characteristic 'dead-heart'. Once inside the shoot the larva is relatively safe from contact insecticides and can only be attacked using systemics. The period of pest vulnerability is clearly the first instar larva as it leaves the eggshell and crawls inside the leaf sheath. Chemical application should be made only when really necessary, and then with care for natural egg mortality is normally high (about 70%), due mostly to predation.

The various ways in which cereal shoot flies can be combated are as follows.

(1) Early sowing – only the young seedling is vulnerable to attack, so by sowing early it is often possible to have the period of crop vulnerability over by the time the flies emerge.

(2) Resistant crop varieties – many cereals show some degree of resistance to shoot fly larvae; certain rice varieties show a high level of resistance.

(3) Insecticides

(a) Seed dressings may be used in areas at high risk, sometimes followed by cover spray later; the usual insecticides employed have been dieldrin, γ-BHC, heptachlor, carbofenothion, etc.

(b) Granules – chlorfenvinphos, endosulfan, disulfoton, and phorate were especially formulated as granules for such use, and other chemicals are being formulated this way now; they are systemic, sometimes slightly fumigant, and persist in soil as granules for several weeks. They are usually applied by the 'bow-wave' technique at drilling.

(c) Cover sprays – usually applied post-emergence along the rows, and the chemicals used for the various shoot flies in the past have included dieldrin, endrin, carbofuran, carbofenothion, dimethoate, formothion, ethoate methyl and parathion, pirimiphos – methyl.

The different shoot flies respond slightly differently to these chemicals and local advice should be sought as to which chemicals are available and which are recommended against the local pests.

Seedlings at the 4–6 leaf stage are attacked – resistant varieties only attacked to 4 leaf stage, but susceptible ones up to 6 leaf stage. Resistance follows deposits of silica in the tissues.

Delia flavibasis (Stein)
(= *Hylemya arambourgi* Seguy)

Common name. Barley Fly
Family. Anthomyiidae
Hosts (main). Barley
(alternative). Maize, wheat, bulrush millet, and some grasses.
Damage. The feeding larva eats the stem of the central shoot, causing a typical shoot borer 'dead-heart'. The central shoot dies, and turns brown, and may be easily pulled out of the plant. One larva may destroy three or four shoots.
Pest status. An important pest of barley in Africa. Heavy infestations occur; if at times of drought, there may be a complete loss of the crop.
Life history. Eggs are usually laid on the soil within 2 cm of the plant, though occasionally recorded on the tips of young leaves. Hatching takes 3–4 days.

The young larvae make their way over the soil surface, climb the plant to just above the first leaf sheaths, and bore down through the tissue to the growing point. This results in the death of the central shoot, producing a 'dead-heart'. The larva remains in this shoot during the first two instars. Soon after the second moult the larva quits that shoot, and attacks either another on the same plant, if tillering has commenced, or else another plant. The new shoot is penetrated by eating through the leaf sheath, and again the central shoot is destroyed. The larva moves to a third or even fourth shoot before reaching maturity some 12 days after hatching.

Pupation takes place in the soil, amongst the plant roots; the pupal stage takes some seven days.

The adult is a medium-sized fly about 7–8 mm long, and looking rather like a housefly; the female has a pointed abdomen and is grey; the male is blackish and has a rounded abdomen apex.
Distribution. Africa: Nigeria, Zimbabwe, Kenya, Uganda, Sudan, Upper Volta, Senegal, Ethiopia, S. Africa, and the S. Arabian peninsula.
Control. The most successful results have been obtained using seed dressings of dieldrin and heptachlor.

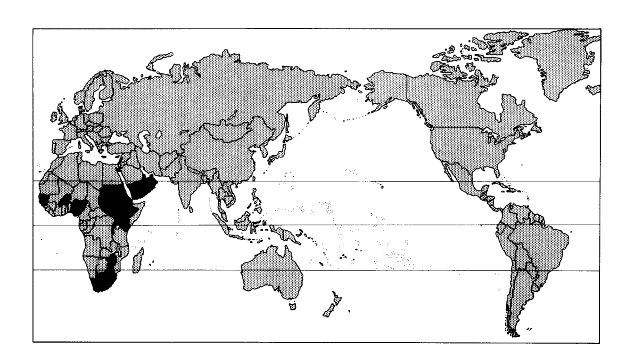
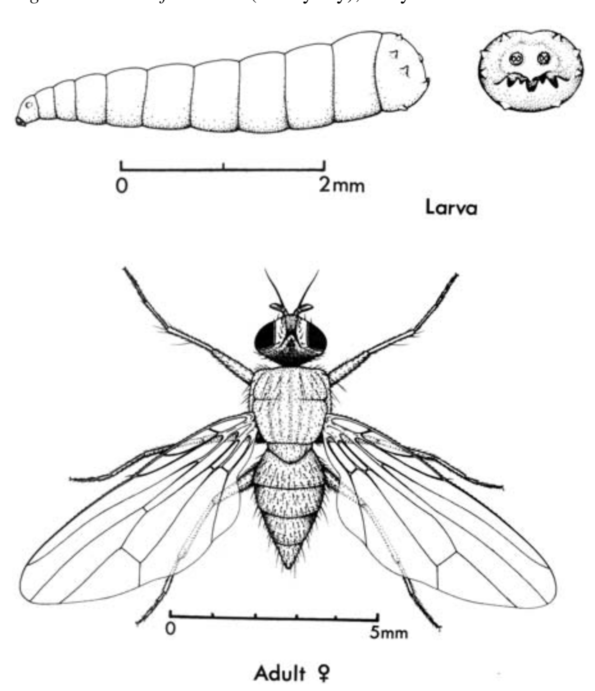


Fig. 9.241. Delia flavibasis (Barley Fly); Kenya.



Delia platura (Meig.)
(= *Hylemya platura* Meig.)
(= *H. cilicrura* (Rond.))
(= *Chortophila cilicrura* Rond.)

Common name. Bean Seed Fly (Corn Seed Maggot)
Family. Anthomyiidae
Hosts (main). Sown seeds of beans and maize.

(alternative). Also onions, tobacco, marrow, cucumber, lettuce, peas, and crucifers, cotton in China

Damage. The maggots bore the cotyledons of sown seeds or into stems and petioles of young seedlings.

Pest status. A serious pest of beans in many areas, and of maize in Europe and the USA; locally important.

Life history. The eggs are laid on disturbed soil. They are elongate, white, with a reticulate pattern. Each female lays about 100 eggs, a few at a time, over a period of 3–4 weeks. Hatching takes 2–4 days.

The larvae are typical maggots, with three instars, taking, 3, 3 and 6–10 days for each stage of development respectively (12–16 days in total).

Pupation takes place in the soil a little way from the plant, 2–4 cm under the soil surface. The puparia are 5 mm long, dark brown, with a posterior circlet of stout projections. In temperate areas over-wintering occurs in the pupal stage, otherwise pupation takes 2–3 weeks.

Adults may live for 4–10 weeks; the female has a greyish pointed abdomen and the male a rounded blackish one. A definite pre-oviposition period occurs in the female from one to several weeks.

There are 2–5 generations per year, according to climatic conditions; the life-cycle may be completed in 4–5 weeks under warm conditions.

Distribution. Almost completely cosmopolitan, occurring from the Arctic Circle down to S. Africa, New Zealand, Tasmania and Argentina, but not recorded from the north-eastern part of S. America, W. Africa, India or the Malaysia/Indonesia peninsula area (CIE map no. A141).

Control. Seed dressings of dieldrin were very successful, but in most areas resistance to dieldrin has become established. In these cases ethion, diazinon and pirimiphos-ethyl and trichloronate have proved to be effective. However, care must be taken with diazinon, for higher dose rates show marked phyto-toxicity; and because of toxicity, the use of trichloronate in some countries is not approved.

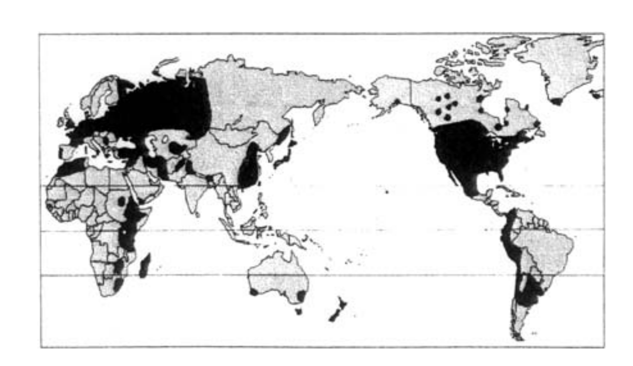
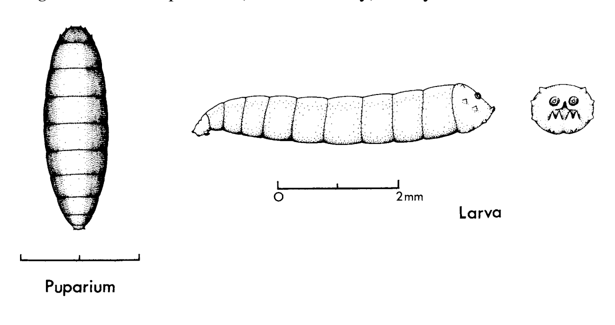
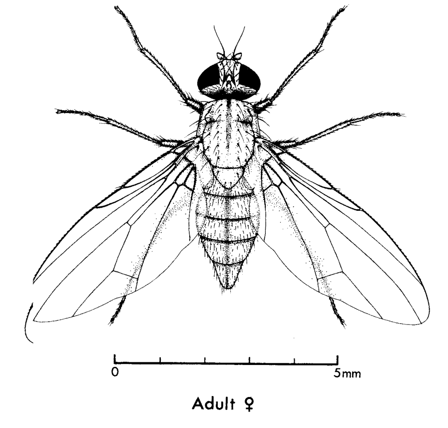


Fig. 9.242. Delia platura (Bean Seed Fly); Kenya.





Root maggots etc. (Diptera; Anthomyiidae)

This is quite a large family of flies, closely related to the Muscidae (some species have been taxonomically shunted back and forth); the main taxonomic character seems to be that the anal vein extends right to the wing margin. Biologically and ecologically the two families can scarcely be separated, if at all; many larvae are saprophagous, feeding on dead organic matter both plant and animal, thus it is not surprising to find many synanthropic species. But some species are truly phytophagous and feed on living plant tissues.

The Anthomyiidae associated with cultivated plants can be grouped into four main assemblages, according to their larval habits, as follows.

(1) Root maggots:
(a) phytophagous species: larvae eat and tunnel intact plant roots, and also intact sown seeds.
(b) saprophagous species: larvae usually associated with the former species and feeding on damaged roots or on organic matter in the soil, and also damaging roots and eating sown seeds.
(2) Cereal shoot flies; larvae bore into the shoots of young cereals and grasses and destroy the growing point, causing a 'dead-heart'.
(3) Leaf miners: larvae make large blotch mines in the leaves of various plants.

A few species bore in plant shoots (shrubs), or stems, or leaf petioles, and their placement above is rather difficult. Some species, such as the 'Bean Seed Fly' complex show a mixture of larval feeding habits in being partly saprophagous and partly phytophagous.

As typical Cyclorrhapha the larvae (maggots) have only mouth-hooks with which to feed, but they clearly cope and are quite successful plant feeders.

Identification of larvae is not easy, but the shape of the mouth-hooks, and both anterior spiracle and posterior spiracular plate, is usually distinctive, and the pattern of sculpturing on the egg chorion is often recognizable. Field identification of crop infestations may be difficult because of the large number of saprophagous species of both Anthomyiidae and Muscidae to be found in soil rich in humus or organic debris (i.e. rotting crop residues), and these are only secondary pests (if that!) in that they are sometimes feeding on roots already damaged by the primary pests, and sometimes already infected by fungal rots. For example several species of *Muscina* (Muscidae) and *Pegohylemyia fugax* are regularly associated with root maggot infestations.

The genera *Delia* and *Hylemya* have been subject to recent taxonomic reappraisal and many of the crop pest species formerly regarded as being in *Hylemya*, or other genera, are now placed in *Delia*. The literature is rather confusing both in regard to generic placement and also species synonymy.

Important pest species of Anthomyiidae

Delia antiqua (Meig.) – (Onion Fly) Holarctic.
Delia arambourgi (Seguy) – (Barley Fly) Africa.
Delia brunnescens (Zett.) – (Carnation Maggot) USA.
Delia coarctata (Fallen) – (Wheat Bulb Fly) Europe, W. Asia.
Delia echinata (Seguy) – (Spinach Stem Fly (Carnation Tip Maggot)) Europe, Japan, USA.
Delia floralis (Fallen) – (Turnip Maggot) Europe, Canada, USA, China.
Delia florilega (Zett.) – ('Bean Seed Fly') Europe.
Delia pilipyga (Vill.) – (Turnip Maggot) China, Japan.
Delia planipalpis (Stein) – (Cruciferous Root Maggot) Canada.
Delia platura (Meig.) – (Bean Seed Fly) worldwide (see page 379).
Delia radicum (L.) – (Cabbage Root Fly) Holarctic (see page 380).
Hylemya cerealis (Gill.) – (Wheat Stem Maggot) Canada.
Hylemya depressa Stein } Found on roots of cruciferous crops in Canada.
Hylemya nidicola (Ald.)
Hylemya flavibasis Stein – (Cereal Root Maggot) S. Europe, Asia Minor, N. Africa.
Hylemya planipalpis (Stein) – (Radish Root Maggot) Canada.
(Some of these species might now be placed in *Delia*, but this point is uncertain.)
Pegohylemyia fugax (Meig.) – saprophagous on cruciferous roots; Europe, Canada.
Pegohylemyia gnava (Meig.) – (Lettuce Seed Fly) Europe.
Pegomya dulcamarae Wood – (Potato Leaf Miner) Japan.
Pegomya hyoscyami (Panzer) – (Beet (Spinach) (Leaf Miner) Fly) Europe, China, Japan, USA, Canada.
Pegomya mixta Vill. – (Beet Leaf Miner) Japan.
Pegomya rubivora (Coq.) – (Loganberry Cane Maggot) Europe, USA.
Pegomya ruficeps Stein – on cabbage; Canada.
Phorbia securis Tien. – (Late Wheat Shoot Fly) Europe.

To give an idea of the extent of the different species that may be encountered in some pest infestation situations the number of species in each genus now recorded from the UK are as follows: *Delia*, 34; *Hylemya*, 5; *Pegohylemyia*, 25; *Pegomya*, 41; *Phorbia*, 9. It should be remembered that most species within a genus have a similar biology, thus most *Pegomya* species are leaf miners, but in different groups of plants.

Control of Anthomyiidae

The species that are partially saprophagous (e.g. bean seed flies) are attracted by manure and rotting vegetable matter in the soil, or even just by recently turned soil; avoidance of such situations and the use of a 'stale' seedbed will tend to discourage infestation.

Many of the truly phytophagous species show striking population fluctuations, and even in areas 'at risk' in some years (often alternate years) populations are very low and damage negligible. Generally for these species it is preferable to 'scout and predict' by taking soil samples for eggs to estimate eventual local populations before deciding on control strategy.

It has been shown for several species of Anthomyiidae that natural levels of predation and parasitism are very high, and in many situations this serves to keep in check the pest populations; this is just as well for some pest species show tremendous powers of population increase. Predation of eggs and young larvae is mostly by Carabidae (Coleoptera) in the soil, and parasitism of the pupae by both Hymenoptera Parasitica and larvae of some Staphylinidae (Coleoptera).

The diversity of crops attacked makes generalization difficult and really means that each crop/pest situation needs to be evaluated separately, especially when considering *Brassica* crops, for sometimes the root is the crop (turnip, radish), other times the central shoot (cabbage), flowerhead (cauliflower) or lateral buds (Brussels sprouts).

General control advice is given below, but it is recommended that local Ministry of Agriculture advice be sought for specific crop/pest situations.

(1) Root maggots
(a) Seed dressings: formerly dieldrin gave excellent control, but resistance is now widespread so bromophos or pirimiphos-methyl are used.
(b) Granules } carbofuran, chlorfenvinphos,
(c) Sprays } chlorprifos or iodofenphos at sowing, trans planting or later, as dips or drenches.

(2) Shoot flies
(a) Seed treatment: HCH, carbophenothion, or chlorfenvinphos.
(b) Granules at sowing: chlorpyrifos or fonofos.
(c) Sprays at sowing: chlorpyrifos.
(d) At egg-hatch: sprays of chlorfenvinphos, chlorpyrifos or pirimiphos-methyl.
(e) At first damage signs: sprays of systemic insecticides; dimethoate, formothion or omethoate.

(3) Leaf miners

The chemicals recommended include acephate, dimethoate, formothion or trichlorphon.

Order **LEPIDOPTERA**

These are moths and butterflies, characterized by having two pairs of membraneous wings, usually large in size; cross-veins are few in number. The body, wings, and appendages are clothed in broad scales. mandibles are almost always vestigial or absent; the mouthparts are generally represented by a suctorial proboscis formed by the maxillae. The larvae are caterpillars, with three pairs of thoracic legs, and usually four pairs of prolegs on the abdomen and a terminal pair of claspers.

Family **Psychidae**

(Bagworm Moths) A small family of about 800 species, mostly (but not all) tropical, with larvae that live inside cases of silk and plant material, and degenerate females which stay inside the pupal bag; they are wingless, and in some species also legless. Several species are crop pests some importance in S.E. Asia.

Family **Gracillariidae**

(Leaf Miners) A cosmopolitan group of 1000 species; tiny moths with larvae that mine leaves of various tree crops (coffee, etc.). It includes now the species of *Leucoptera* (Coffee Leaf Miners).

Family **Phyllocnistidae**

(Leaf Miners) The genus *Phyllocnistis* has more than 50 species; the adults are minute and very delicate; the leaf-mining larvae are unusual in being apodous.

Family **Sesiidae** (= Aegeriidae)

(Clearwings) These are mostly small moths, characterized by the absence of scales from the greater part of both pairs of wings; the antennae are often dilated or knobbed, and the abdomen is terminated by a conspicuous fan-like tuft of scales. The forewing is usually narrow resulting from considerable reduction of the anal area. This small family (about 20 species) is characteristic of the northern hemisphere; they are diurnal fliers and superficially resemble wasps. The larvae feed in the wood of trees and bushes or in the rootstock of plants.

Family **Yponomeutidae**

A family of about 1000 species, now including the Plutellidae. Only a few species are important crop pests, several are pests of temperate fruit trees. Some of the larvae make slight webbing, and some bore into shoots, buds and fruits.

Family **Gelechiidae**

This family contains some 400 genera and 4000 species. The forewings are trapezoidal in shape and the wing venation is characteristic. The larvae generally feed among spun leaves or shoots.

Family **Cossidae**

(Goat Moths; Carpenter Moths) These are large moths, of nocturnal habits, and widely distributed. The body is large and heavy, and the wings rather long and narrow. The larvae are borers in trees, but are sometimes found in herbaceous plants and reeds. The larvae are unable to digest cellulose and obtain their nutriment from the sap; they accordingly consume large quantities of wood; the tunnels they make are very extensive and larval life is long, in temperate regions being up to two years.

Family **Metarbelidae**

(Wood-borer Moths) A small tropical family found in Africa and Asia whose larvae eat bark of trees and make tunnels into the wood. The adults are nocturnal. The genus *Indarbela* contains many species, some of which are pests on woody plants.

Family **Limacodidae** (= Cochlidiidae)

A small family, mostly tropical in distribution; the larvae are called ‘slug caterpillars’ and have short, thick, fleshy bodies, a small retractile head, and tiny thoracic legs. Some bear urticating setae (‘hairs’) and are called ‘stinging caterpillars’. Body segmentation is obscure and prolegs are absent. A number of species are pests of palms, particularly oil palms in S.E. Asia, and many species (in several genera) are pests of tea.

Family **Tortricidae**

These are small moths, with vestigial maxillary palps, or else they are absent; they are classified by their wing venation. They have wide wings with shortish wing fringes. Most species are temperate rather than tropical in distribution. The eggs are flattened and oval, usually smooth. The larvae live concealed, usually in rolled or joined leaves, or in shoots spun together, or else in stems, fruit, buds, flower heads, seed pods, or roots. The pupa is usually found in the situation where the larvae feed, and it is protruded from the cocoon prior to the emergence of the adult. There are 1500 species described in this family. The caterpillars are often referred to in American literature as ‘bud-worms’.

Family **Pyralidae**

This family is largely tropical in distribution, and relatively scarce elsewhere. Various other families are sometimes included under the Pyralidae, otherwise they collectively constitute the Pyraloidea, a very large group. The larvae usually feed on dry (or decaying) vegetable matter; a number are stem borers in Gramineae, most are leaf-eaters. The crochets on the prolegs are either in a pair of transverse bands, or a more or less complete circle of biordinate crochets. Many of the larvae produce silk, and may roll leaves with the silk.

Family **Nymphalidae**

(Four-footed Butterflies) This is the dominant family of butterflies and one of the largest of all the Lepidoptera, including about 5000 species. The forelegs of both sexes are reduced in size and usually folded on the thorax and functionally impotent. The antennae are slender and abruptly clubbed; the labial palps long; maxillary palps obsolete. There are several very distinct subfamilies.

Family **Lycaenidae**

(Blues, Coppers, Hairstreaks) Small to mediumsized butterflies, well represented in most regions. The predominant colour of the upper surface of the wings is metallic blue or coppery-brown; the hind-wings often have delicate 'tails'. All the legs are functional. The sexes often exhibit distinct sexual dimorphism in colour. Most of the larvae are onisciform (tapering at each end), and with broad projecting sides concealing the legs. Some of the larvae are carnivorous. Only a very few species are pests.

Family **Pieridae**

(Whites, Yellows, etc.) A large group of butterflies with normal legs, usually white or yellow in colour. Several species of *Pieris* are important pests of Cruciferae throughout the world. The family is equally well-represented in the tropics and in temperate regions.

Family **Papilionidae**

(Swallowtails) A large family of tropical butterflies, but some are temperate; about 600 species are known. Most have the hindwings drawn out into conspicuous tails. Only a very few species are pests.

Some species are strikingly polymorphic; the pupae are variable in form.

Family **Hesperiidae**

(Skippers) A very large family, widely distributed, somewhat intermediate between the butterflies and the moths. They are called Skippers because of their darting flight. The body is stout; the antennae have a gradually expanding club, often ending in a hook; the wings are proportionally smaller than in most butterflies, and are often held partly open at rest. The larvae are often concealed in the host foliage, making webs or joining leaves together with silken threads.

Family **Drepanidae**

(Hook Tips) A small family most represented in the Indo-Malaysian region. The apex of the forewing is generally falcate. The larvae are rather slender, and without claspers on the ultimate segment, and the anal extremity is prolonged into a slender projection which is raised when at rest; the other body segments are often humped.

Family **Geometridae**

(Loopers, or Geometers) A very large family with more than 12 000 species. The adults are typically slender-bodied with relatively large wings; not strong fliers; the wings are often held horizontally at rest. In some genera the females are apterous. The caterpillars are elongate and slender and only have one pair of prolegs (on segment six) in addition to the terminal claspers; they move in a looping manner, but at rest are cryptic and resemble a twig. Many species of larvae are defoliators of trees.

Family **Epiplemidae**

A small group of about 550 species; inconspicuous in appearance; they commonly rest during the day with the forewings rolled up in a peculiar manner, while the hindwings are held to the sides of the body. They occur on all continents, but are best developed in Papua and thereabouts.

Family **Saturniidae** (= Attacidae)

(Emperor Moths; Silkworm Moths) The largest and most splendid moths belong to this essentially tropical family. The larvae spin silk to make the cocoon, and are the source of some types of 'wild silk'. A few species are minor pests of tree crops in warmer climates.

Family **Sphingidae**

(Hawk Moths) An important family of moderatesized to very large moths; including at least 1000 species; essentially a tropical group, but some species are temperate, and some cosmopolitan. The adults are characterized by the elongate forewings with their very oblique outer margin; the proboscis is typically very long (up to 25 cm). The larvae are smooth, and the eighth abdominal segment always bears an obliquely projecting dorsal horn – in the USA the larvae are called 'hornworms'.

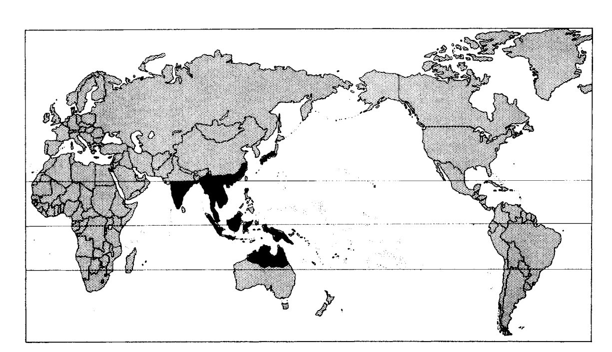
Family **Noctuidae** (= Agrotidae)

The largest family of Lepidoptera, with more than 6000 species described, all bearing very similar characteristics. They are mostly medium-sized and rather dull-coloured moths; nocturnal in habit, though a few species are crepuscular; they are very attracted to light at night. There are many pest species; some of the larvae are leaf eaters, some cutworms, some armyworms, stem borers, and fruit borers, and some adults are fruit piercers. The crochets on the prolegs are all of one size, arranged in a semi-circle.

Clania spp. etc.

Common name. Bagworms
Family. Psychidae
Hosts. Many bagworms show polyphagous feeding habits, and have been recorded from many different host plants. *Clania* spp. are being used as an example typifying the whole family, for field recognition purposes.
Damage. All bagworms do the same type of damage, that is they defoliate the host by eating the leaves, and the plant generally is festooned with the hanging cases.
Pest status. Bagworms generally are fairly minor pests on many different crops, with the exception of some on palms (see next page) which are very serious in Malaysia. But they do occur very regularly throughout the tropical regions of the world.
Life history. The male moth is winged, usually has a characteristically elongate abdomen, and flies at night to search for females. *Clania* males have a wingspan of 28–35 mm, but several other bagworms of economic importance are quite a lot smaller, with males having a wingspan of only 15 mm. The female moth is wingless and legless and never leaves the bag; after mating she becomes virtually just a sac of eggs. The eggs, which number from about 200 to 3000 according to species, hatch within the bag and the young caterpillars crawl out on to the foliage of the host plant. In some species the tiny larvae spin silken threads which enable them to be lifted by air currents and carried by the wind. This is the dispersive stage. Other larvae spread from tree to tree within plantations where foliage from adjacent trees touch. The larvae soon build a tiny case out of leaf fragments in which the body is protected. Small larvae usually scrape the epidermis and make 'windows' in the leaf lamina, but as they become larger they eat the whole blade of the leaf, either from the lamina margin or make holes. As the larvae grow the case is enlarged. When feeding, the thorax and head protrude from the case, and attachment is effected by the thoracic legs holding on to the leaf. For pupation the bag is firmly attached to the leaf or twig by silken threads and dangles from the foliage. If the emerging adult is male it leaves the case by the ventral end and the pupal exuvium protrudes from the case. If it is a female then she just remains inside the case and secretes sex pheromones to guide the searching male moths to her presence.

In some large species the life-cycle takes 3–4 months, but for smaller ones generally about a month. There may be several generations per year in the warmer parts of the tropics.
Distribution. Bagworms are found throughout the tropical and subtropical parts of the world, but *Clania* species are only recorded from India and Australia, S.E. Asia, up to Japan. Similar species found in Africa.
Control. Natural parasitism is generally high amongst bagworms and so only occasionally is chemical control required. Trichlorphon has generally been effective as a foliar spray.



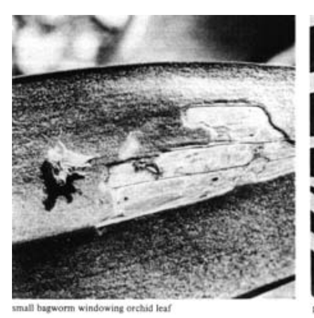


Clania larvae on *Thuja*

Fig. 9.243. Bagworms (Psychidae) in S.E. Asia.



Palm devastated by bagworms: sarawak



small bagworm windowing orchid leaf



palm leaf eaten by larvae

Mahasena corbetti Tams

Common name. Coconut Case Caterpillar
Family. Psychidae
Hosts (main). Coconut and oil palm.
(alternative). *Citrus*, kapok, derris, *Aleurites*, *Cupressus*, and others.
Damage. In severe infestations there may be total defoliation, not only of whole palms but occasionally of entire plantations. The leaf lamina is eaten away so that all that remains of the frond is the midrib and lateral veins.
Pest status. In Malaysia this has been a serious pest of oil palm for several years (B.J. Wood, 1968), but it does sporadic damage to coconut palms throughout S.E. Asia.
Life history. The young caterpillars scrape the leaf epidermis and make small windows, but as they grow larger they eat holes in the leaf, and the older caterpillars eat large areas of leaf lamina and use large pieces of leaf for their cases.

This species lays a large number of eggs, often more than 3000 per female, which accounts for the enormous localized populations that may develop. In Sabah in 1966 some palms had 300–500 larvae on a single frond, and damage was spectacular.

Larvae grow to about 35 mm in body length before pupation; and the life-cycle takes about 3–4 months.

Adult males measure 25–30 mm in wingspan, and are normally winged brown-coloured moths. As with other Psychidae the female is degenerate and consists of little more than a large bag of eggs within her pupal bag.

The young caterpillars use long silken strands to aid their dispersal; they can be windborne for short distances from tree to tree; most dispersal is actually thought to be by the caterpillars walking along the ground from tree to tree.
Distribution. From Malaysia and Thailand, through S.E. Asia, to Papua New Guinea.
Control. Parasitism of the larvae by parasitic Hymenoptera and Tachinidae can be quite high, but this pest does have enormous reproductive potential and so outbreaks invariably occur. Trichlorphon and DDT have both been used successfully in the past against this pest.

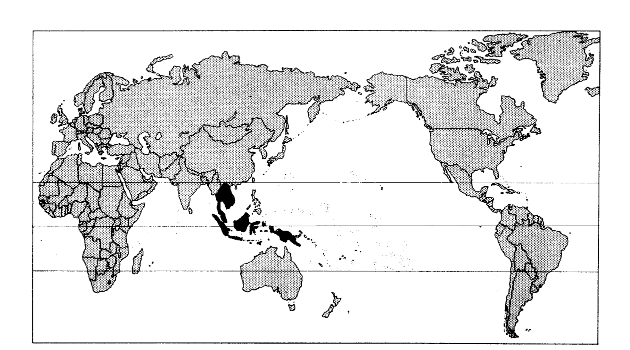
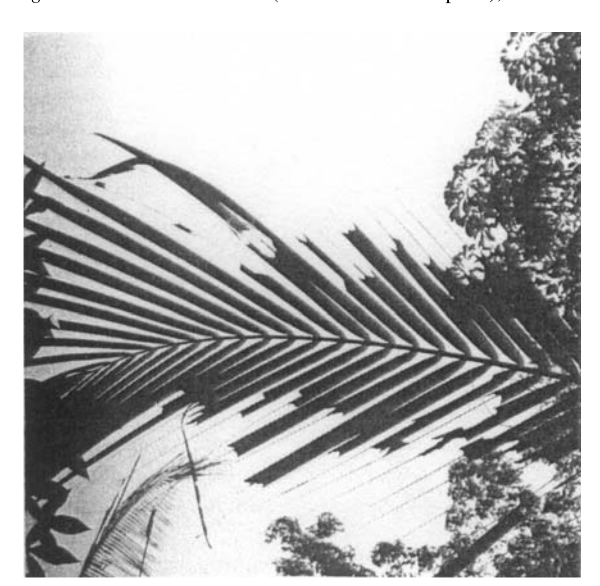


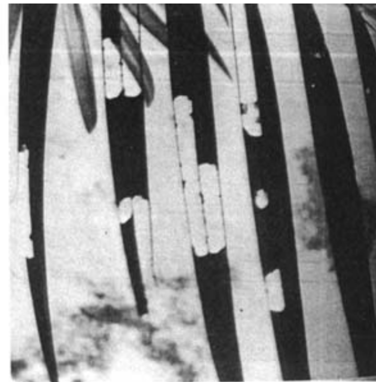
Fig. 9.244. Mahasena corbetti (Coconut Case Caterpillar); Borneo.







bagworm



damage

Leucoptera spp.

caffeina Wash.
coma Ghesq.
meyricki Ghesq.
coffeella (Guér.)

Common name. Coffee Leaf Miners
Family. Lyonetiidae
Hosts (main). Coffee, *arabica* mostly but sometimes *robusta* may be equally attacked.

(alternative). *Leucoptera* can breed on certain wild rubiaceous shrubs (*Pavetta* spp., and a *Tricalysia* sp.) in addition to other species of *Coffea*.

Damage. Infested plants have brown irregular blotches on the upper surface of leaves; the blotch mine is inhabited by a number of small white caterpillars. Mined leaves are usually shed prematurely.

Pest status. A major pest of coffee in Africa and S. America. In E. Africa, where both coffee species occur, *L. meyricki* is dominant in unshaded coffee and *L. caffeina* in shaded coffee. All cultivated species of coffee are attacked.

Life history. Eggs are laid on the upper surface of the leaf; roughly oval but with a broad base on the leaf surface; they are silver when laid, turning brown just prior to hatching. Eggs of *L. meyricki* are scattered in small groups; those of *L. caffeina* are laid touching each other in a neat row along a main vein. Hatching takes place after 1–2 weeks, according to temperature.

The larva is a small, white caterpillar; it bores through the floor of the egg straight into the leaf and mines just below the upper epidermis. The mines of each *L. meyricki* caterpillar are originally separate but after a few days they join up to form one large blotch mine. When a caterpillar is fully grown it cuts a semi-circular slit in the dead epidermis, comes out of the mine and lowers itself on a silken thread; it is then about 8 mm long. The total larval period is 17–35 days in the field, according to temperature.

The mature larva settles on a dead leaf on the ground or the underside of a living leaf and spins a H-shaped white cocoon about 7 mm long. In this it pupates emerging as the adult moth 1–2 weeks later.

The adults are tiny white moths about 2 mm long, and they live in the field for about two weeks. During this period the female lays about 75 eggs, mostly during the first few days after emergence.

The life-cycle takes some 4–6 weeks to complete, and in most parts breeding is continuous, there being as many as 8–9 generations per year.

Distribution. *L. meyricki* is the commonest African species; and this together with *L. coma* and *L. caffeina* are found only in Africa, being recorded from Ivory Coast, Angola, Zaïre, E. Africa, Ethiopia, and Madagascar (CIE map no. A316).

L. coffeella is confined to S. and C. America, the W. Indies and Madagascar (CIE map no. A315).

Control. Out of a wide range of insecticides which have given varying levels of control the two most consistently successful are probably fenitrothion and fenthion as foliar sprays. A second spray may be required 2–3 weeks after the first.

Spraying should as far as possible be done when a low proportion of the population is in the cocoon stage for these individuals will not be killed by the insecticide. The best time for spraying is about one week after the period when moths were most numerous, for then most of the insect population will consist of eggs or young larvae and a good kill is more likely to be achieved.

As an alternative to spraying granules can be applied to the soil – aldicarb, carbofuran, and disulfoton are effective, but they have high mammalian toxicity and require great care in their use.

There are possibilities for classical biological control using parasitic Hymenoptera.

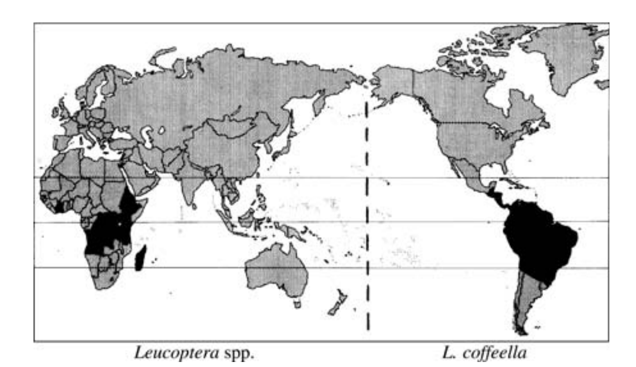
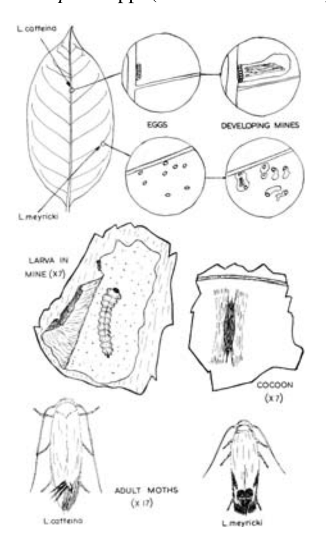


Fig. 9.245. Leucoptera spp. (Coffee Leaf Miners); Kenya.



Leaf-mining microlepidoptera

This is a large assemblage of tiny moths (3–8 mm total length), belonging to the heterogeneous group referred to as the microlepidoptera, whose larvae mine the leaves of both angiosperms and gymnosperms. The moths are seldom seen because of their tiny size, but the larval mines are often quite conspicuous. Some of the groups here included are not closely related, but are often considered en masse because of their tiny size and similarity of larval habits.

To the agriculturalist they are collectively of little importance (except for just a few species, *Leucoptera* spp.), but to the entomologists and ecologists they are of considerable interest (see Wilkinson, 1982).

The larvae of most species make simple mines, sometimes entirely linear winding tunnels, sometimes blotch mines, and sometimes the mine starts in a linear manner and terminates in a large blotch. The casebearers start as leaf miners, but the later larval instars leave the mine and build small cases in which the caterpillar lives while feeding externally on the leaf epidermis. The skeletonizers spend the first few instars (usually 1–3) internally as miners, but later their eating includes one epidermis so they become exposed as 'leaf skeletonizers'.

Pupation takes place either in the mine, or in leaf litter, or often the edge of the leaf is turned over dorsally with silken threads and pupation takes place under the fold; the casebearers pupate within the larval case.

Most species mine only in the leaves, but some prefer buds (which are, after all, just a collection of young leaves on a telescoped shoot); one or two species mine the bark of trees.

The host plants are mostly trees and woody shrubs, but some herbaceous plants are used; the vast majority of hosts are the local deciduous forest trees such as oaks, elms, beeches, willows, etc.

Sub-order Dacnonypha

Eriocraniidae
A small primitive family with larvae as leaf miners in angiosperms or in the seeds of gymnosperms; Holarctic and Australian in distribution, regular hosts include oaks, birch, hazel and hornbeam. The mine is a large blotch, sometimes starting as a linear mine; in the blotch are to be seen long threads of frass that are characteristic.

Sub-order Monotrysia

Nepticulidae
A largish, rather primitive family of tiny moths, about the smallest Lepidoptera known with wingspan 3–10 mm; worldwide in distribution; as an indication of their abundance there are 67 species recorded in the UK. Some larvae start as leaf tunnel (gallery) miners but end in making a blotch mine; others do not end in a blotch mine; some species mine other parts of the plant body, such as buds, stem or bark. Three British species mine leaf petioles or midribs. The shape of the mine and the nature of the frass track can be diagnostic with experience. Pupation usually takes place in the leaf litter inside a silken cocoon. The more important (pest) species include:

Stigmella aurella (F.) – (Rubus Leaf Miner) Europe, N. Africa, Near East.
Stigmella anomalella (Goeze) – (Rose Leaf Miner) throughout Europe.
Stigmella malella (Stainton) – (Apple Pygmy Moth) Europe, including Italy.
Stigmella pomella (Vaughan) – (Apple Leaf Miner) throughout Europe.
Stigmella gossypii (F. & L.) – (Cotton Leaf Miner) USA.
Stigmella juglandifoliella (Clemens) – (Pecan Serpentine Leaf Miner) USA.
Stigmella spp. – 70 other species in UK; mostly leaf miners in trees (fruit trees, hazelnut and ornamentals).
Nepticula is now regarded as a junior synonym of *Stigmella*.

Incurvariidae
A small, rather primitive family, with larvae that are leaf miners mostly in herbaceous plants (with a few bud borers); some emerge from the mines and construct a tiny case for further feeding and pupation. The few pest species include:

Lampronia capitella (Clerck) – (Currant Shoot Moth) Europe, Asia to E. Siberia.
Lampronia rubiella (Bjerk.) – (Raspberry (Bud) Moth) Europe, Asia, USA, Canada.

Tischeriidae
A small but widespread family, rather primitive; the larvae are leaf miners and many have legs reduced, they eject their frass from the tunnel. Formerly placed in the Lyonetiidae; most species occur in America, but some in Europe, India and S. Africa. The mine is a blotch lined with silk; pupation occurs in the mine, and the pupal exuvium protrudes after emergence. Few species are recorded as pests:

Tischeria malifoliella Clemens – (Apple Leaf Trumpet Miner) USA.
Tischeria marginea (How.) – (Rubus Leaf Miner) Europe, Near East, N. Africa.
Tischeria sp. – (Peach Leaf Miner) China.
Tischeria spp. – (Chestnut Leaf Miners) Europe.

Sub-order Ditrysia

Lyonetiidae
(In Imms, included in Gracillariidae)

Quite a large 'family' – regarded by some as a heterogeneous assemblage; worldwide in distribution; some species are leaf-miners throughout their larval life, but some are only leaf miners for instars 1–3, and the fourth instar becomes a skeletonizer by eating one epidermis. Pest species include:

Bedellia gossypii Tun. – (Cotton Leaf Miner) Australia.
B. orchilella Wals. – (Sweet Potato Leaf Miner) USA.
Bedellia somnulentella (Zeller) – (Sweet Potato Leaf Miner) pantropical.
Bucculatrix pyrivorella Kuroko – (Pear Leaf Miner) Japan.
Bucculatrix thurberiella Busck – (Cotton Leaf Perforator) USA, C. and S. America.
Crobylophora spp. – (Coffee Leaf Miners) C. Africa.
Leucoptera coffeella (Guer.) – (Coffee Leaf Miner) C. and S. America (CIE map no. A.315).
Leucoptera malifoliella (Costa) (Apple (Pear) Leaf Blister Moth) Europe, China.
Leucoptera spp. (4) – (Coffee Leaf Miners) Africa (CIE map no. A.316).
Lyonetia clerkella (L.) – (Apple (Peach) Leaf Miner) Europe, China, Japan.
L. prunifoliella Mats. – (Plum Leaf Miner) Japan, Europe, Asia Minor.
Opogona glycyphaga Meyr. – sugarcane, banana skins; Australia.
Opogona spp. – (Sugarcane Leaf Miners) Africa, S.E. Asia, Hawaii.

Gracillariidae (blotch miners)
A large and cosmopolitan family, with more than 1000 species, of tiny moths with narrow wings and long fringes whose larvae mostly make blotch mines in leaves. Some of the more important pest species include:
Acrocercops astourota Meyr. – (Pear Leaf Miner) China.
A bifasciata Wlsm. – (Cotton Leaf Miner) Africa.
Callisto denticulella (Thnb.)–(Apple Leaf Miner) Europe.
Caloptilia spp. – on many ornamentals; USA.
Caloptilia soyella Dev. – (Soybean Leaf Roller) Japan.
Caloptilia theivora Wals. – (Tea Leaf Roller) Japan.
Cuphodes dispyrosella Issiki – (Persimmon Leaf Miner) Japan.
Gracillaria spp. – on many ornamentals; USA.
Marmara elotella (Busck) – (Apple Bark Miner) USA.
Marmara pomonella (Busck) – (Apple Fruit Miner) USA.
Phyllonorycter (= *Lithocolletis*) spp. – ((Oak) Leaf Miners) Europe, USA.
Phyllonorycter spp. (11) – on Malvaceae and Leguminosae; Australia.
P. blancardella (F.) – (Apple Leaf Miner) Europe.
P. crataegella (Clemens) – (Apple Blotch Leaf Miner) USA.
P. pomonella (zeller) – (Plum Leaf Miner) Europe.
P. ringoneella Mats. – (Apple Leaf Miner) Japan.
P. triflorella Reger – (Apple Leaf Miner) China.
Spulerina astaurcta Meyr. – (Pear Bark Miner) Japan.

Coleophoridae (= Eupistidae) (casebearer moths)
Quite a large group, more than 400 species recorded; Holarctic in distribution, with 95 British species. All the larvae are leaf miners in their first instars, some remain leaf miners and others become casebearers and feed externally; the leaf miners eat the entire mesophyll, leaving just upper and lower epidermis intact, so the mine looks like a window; most pupate inside a case on branches or the tree trunk. Most species are placed in the very large genus *Coleophora*; there are a few pest species to be noted:
Acrobasis caryae (Horn) – (Pecan Nut Casebearer) USA.
A. juglandis (Le Baron) – (Pecan Leaf Casebearer) USA.
C. anatipennella (Hübner) – (Cherry Pistol Casebearer) Europe.
C. coracipennella (Hübner) – (Apple and Plum Casebearer) Europe.
C. caryaefoliella Clemens – (Pecan Cigar Casebearer) USA.
C. ochroneura – larvae in flower head of white clover; Australia, New Zealand.
C. pruniella Clemens – (Cherry Casebearer) USA.
C. serratella L. – (Apple Casebearer) Japan.
C. ringoniella Oku – (Apple Pistol Casebearer) Japan.
Coleophora spp. – elms, etc.; Europe, Asia, USA.

Phyllocnistidae
This family is represented by a single large genus (50 species) of tiny moths, quite cosmopolitan in distribution; the larvae are all leaf miners and are characterized by being apodous. There is only one pest species of any consequence, although several species are quite abundant.
Phyllocnistis citrella (Stnt.) – (Citrus Leaf Miner) Africa and Asia (CIE map no. A.274).
Phyllocnistis toparca Meyr. – (Grapevine Leaf Miner) India, Japan.
Phyllocnistis spp. – various common trees and grapevine; Europe, Asia, India, Japan.

Control of leaf miners (Microlepidoptera)

Damage is seldom serious, although the leaf mines are usually quite conspicuous and often common, but sometimes economic injury is inflicted.

Natural parasitism levels are usually high; many species of Hymenoptera Parasitica are involved and any insecticide use should be done very carefully so as to avoid upsetting the high level of natural control.

Chemical control involves the use of insecticides with penetrant action in order to kill the larvae *in situ*, and some systemic chemicals are also effective. The other alternative is to use insecticides against the adult moths on the plant foliage prior to oviposition and this method requires very careful timing. The chemicals recommended include diazinon, chlorpyrifos, fenthion, fenitrothion, and phosphamidon.

Phyllocnistis citrella (Stnt.)

Common name. Citrus Leaf Miner
Family. Phyllocnistidae (formerly in Gracillariidae)
Hosts (main). Species of *Citrus*
(alternative). Other members of the family Rutaceae.
Damage. The feeding larvae make broad serpentine galleries (mines) in the leaves, leaving a distinctive dark line of faecal pellets along the centre of the tunnel. In young leaves the lamina folds over and twists, with a high degree of distortion; badly damaged leaves dry out and are clearly of little use photosynthetically.
Pest status. In young plants the damage can be quite serious. On older plants infestation levels may be very high occasionally, so that control measures may be required.
Life history. Eggs are laid singly, by the midrib on the underneath of the leaf; they are flattened, oval and white. Incubation takes 3–5 days. On hatching the young larva penetrates the epidermis and commences burrowing, eventually making a long serpentine, convoluted mine which is conspicuously silvery in colour owing to the air trapped under the epidermis. As with all leaf-mining caterpillars, the larva leaves its faecal pellets in a line down the centre of the tunnel, for it lies in the tunnel on its ventral surface. (In most leaf-mining Diptera the larva lies on its side in the tunnel and so the faecal pellets are deposited along the edges of the tunnel and are not at all conspicuous.) Larval development takes usually 16–18 days, and the mature larvae is about 3.5 mm long, and yellowish-white in colour. Pupation takes place at the edge of the leaf and the lamina margin is turned over to protect the pupa underneath.

The adult is a tiny moth 2–3 mm in body length with a wingspan of 5–8 mm, in colour greyish-white, with black eyes and four black stripes across each forewing; the hindwings are feathery.

Total life-cycle takes about three weeks, and usually there are five or more generations per year.
Distribution. Widely distributed throughout S.E. Asia, up to China, Korea and Japan, and across the Philippines and Indonesia, to Papua New Guinea and the northern tip of Australia (NSW & Queensland). In Africa it is only recorded from the Sudan and Ethiopia (CIE map no. A274).
Control. When required, it is recommended that either diazinon or phosphamidon (e.c.) be applied as a foliar spray, at weekly intervals on young plants or fortnightly on mature *Citrus*.

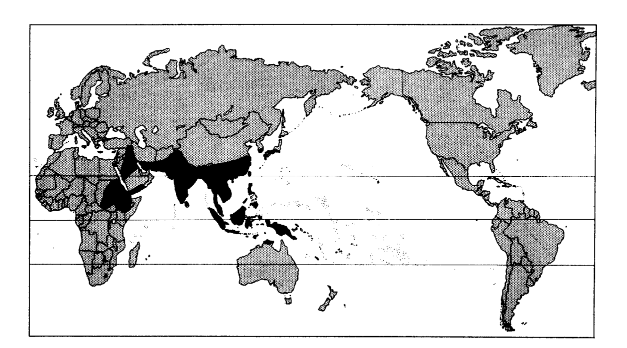


Fig. 9.246. Phyllocnistis citrella (Citrus Leaf Miner); S. China.

larval mine in leaf of mandarin orange



Synanthedon dasysceles Bradley

Common name. Sweet Potato Clearwing
Family. Sesiidae
Hosts (main). Sweet Potato
(alternative). Not known.
Damage. The larvae burrow into the vines, and sometimes also into the tubers. It can be a pest of sweet potato tubers in stores. The vine base is characteristically swollen and is traversed by feeding galleries.
Pest status. The three closely related species of *Synanthedon* are regularly found in sweet potato in E. Africa but they are not really serious pests.
Life history. Eggs are laid in clusters on the stems and leaf stalks; hatching takes a few days.

The white caterpillars bore into the stems (vines) where they tunnel down to the stem base which gradually swells.

Pupation takes place in the tunnels in the vines.

The adult moths are grey-brown, without the reddish colour that the other two species possess, and with the abdomen blackish-brown with a pale central line. The male wingspan is 20–22 mm; the female 17–25 mm; the wings are hyaline, hence the common name of 'clearwing'. This species is characterized by having extensive rough scaling on the hindlegs (tibia and tarsus) which is longer in the male, and the white markings on the basal part of the hindlegs of the female.
Distribution. E. Africa.

Two other closely related species are also found on sweet potato in E. Africa, these being *S. leptosceles* and *S. erythromma*.
Control. Not really required.

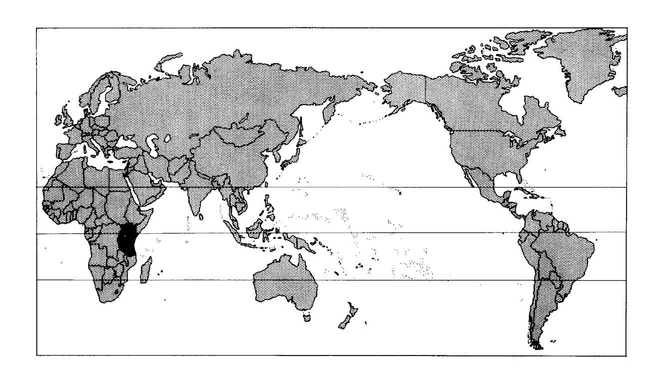
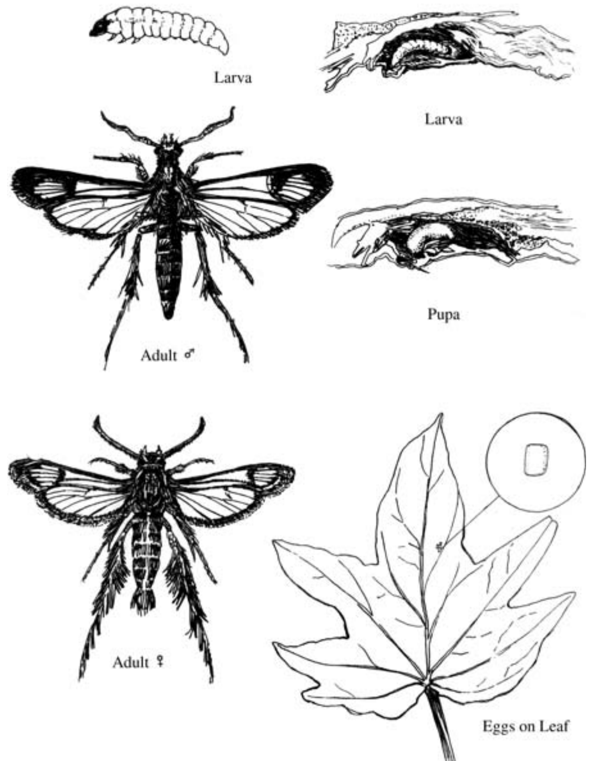


Fig. 9.247. Synanthedon sp. (Sweet Potato Clearwing); Kenya



Clearwing moths (Lepidoptera: Sesiidae (= Aegeriidae))

This family is characterized by the adult moths having the forewings elongate and narrow, and both wings largely devoid of scales so they are clear; the overall effect is that they look remarkably like wasps, further enhanced in some species by the yellow banding on the black body. The banded abdomen terminates in a tuft of scales. Adults are diurnal and fly rapidly in warm sunshine; they are often to be seen sitting on exposed foliage on sunny days.

Some species are tropical, but the group is essentially a Holarctic (northern temperate) one. The tropical species have larvae that bore the vines of sweet potato and cucurbits; but most temperate species bore in the branches and trunks of trees and woody shrubs. However, a few non-pest species bore in the roots of herbaceous plants such as *Rumex*, *Armeria* and some legumes. The trees most favoured as hosts include willows, poplars, birches, oaks, but various fruit trees are also attacked.

Control is seldom really needed and most attacks are sporadic and local. Once the larvae are actually boring inside the branches they are extremely difficult to kill with insecticides as contact cannot be effected.

Some pest species of Sesiidae

Conopia hector Butler – (Cherry Tree Borer) Japan.
Melittia calabaza D. & E. – (Southwestern Squash Vine Borer) USA.
Melittia cucurbitae (Harris) – (Squash Vine Borer) USA.
Nokona regale Butler – (Grape Clearwing) Japan.
Paranthrenopsis constricta Butler – (Rose Clearwing) Japan.
Sanninoidea exitiosa (Say) – (Peach Tree Borer) USA.
Sannina uroceriformis Wlk. – (Persimmon Borer) USA.
Sesia apiformis (Clerk) – (Hornet Clearwing) poplars; Europe and USA.
Synanthedon bibionipennis (Bois.) – (Strawberry Crown Moth) USA.
Synanthedon myopaeformis (Bork.) – (Apple Clearwing) Europe, Asia Minor, USSR.
Synanthedon pictipes (G. & R.) – (Lesser Peach Tree Borer) USA.
Synanthedon pyri (Harris) – (Apple Bark Borer) USA.
Synanthedon salmachus (L.) – (Currant Clearwing) Europe, Asia, Australia, Canada, USA (see page 388).
Synanthedon vespiformis (L.)–(Yellow-legged Clearwing) chestnut, walnut, etc.; Europe, W. Asia.
Synanthedon spp. (3) – (Sweet Potato Clearwings) E. Africa.
Pennisetia marginata (Harris)–(Raspberry Crown Borer) USA.
Vitacea polistiformis (Harris)–(Grape Root Borer) USA.

Plutella xylostella (L.)
(= *Plutella maculipennis* (Curtis)

Common name. Diamond-back Moth
Family. Yponomeutidae
Hosts (main). *Brassica* species
(alternative). Cultivated and wild Cruciferae.
Damage. First-instar larvae mine the leaves, entering from the underside, but later instars also eat the lower epidermis making small 'windows' in the leaf; after a time the upper epidermis often ruptures so that a small hole results. With heavy infestations the entire plant is devastated.
Pest status. A very common and widespread pest of Cruciferae, often serious, especially in some of the warmer parts of the world. In hot dry weather attacks are particularly damaging.
Life history. The tiny yellow eggs are laid on the upper surface of the leaves, either singly or in small groups; hatching takes place after 3–8 days. Each female moth lays 50–150 eggs.

The caterpillar is pale green, with a tapering body widest in the middle; head is black when hatched but turns paler yellow when mature; length about 12 mm. If disturbed the larvae wriggle violently and may drop off the leaf suspended by a silken thread. Larval development takes 14–28 days.

Pupation takes place in a gauzy silken cocoon stuck to the plant foliage; the pupa is about 9 mm long; development takes 5–10 days under warm conditions.

The adult is a small grey moth, about 6 mm long and wingspan 15 mm. Along the hind margin of each forewing are three pale triangular marks, and when the wings are closed the marks form a diamond pattern, hence the common name. The moths live for about two weeks, and regularly migrate in both Europe and N. America. In northern Canada they do not survive over winter; in the early summer migrants from the USA start new infestations. In British Columbia there are 2–3 generations per year; Ontario may have six; in lowland Malaysia 15 generations are recorded. Under warm conditions the life-cycle can be completed in 12–15 days.
Distribution. Totally cosmopolitan in distribution, in fact the most widespread pest species of Lepidoptera; almost completely worldwide, extending right into the Arctic Circle (CIE map no. A.32).
Control. In many countries this pest has developed resistance to the usual insecticides and so local Ministry of Agriculture advice should be sought. See page for advice on the 'control of cabbage caterpillars'.

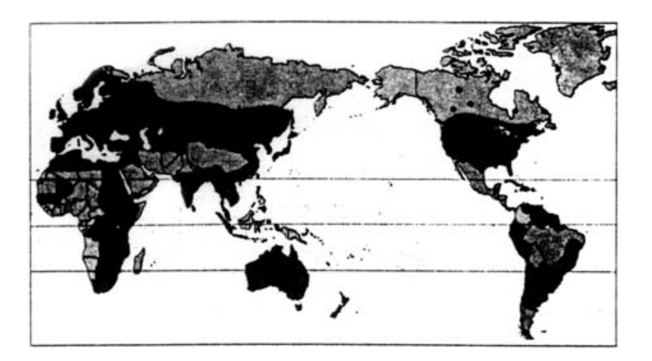
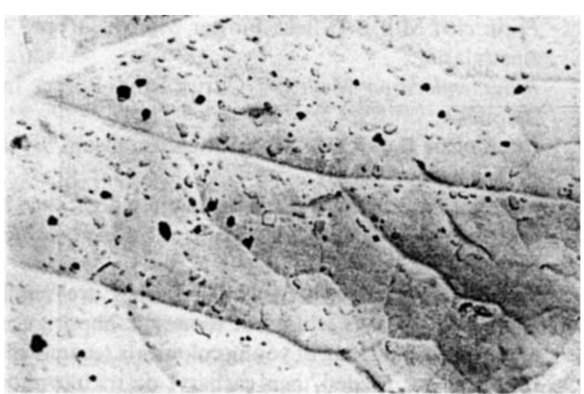
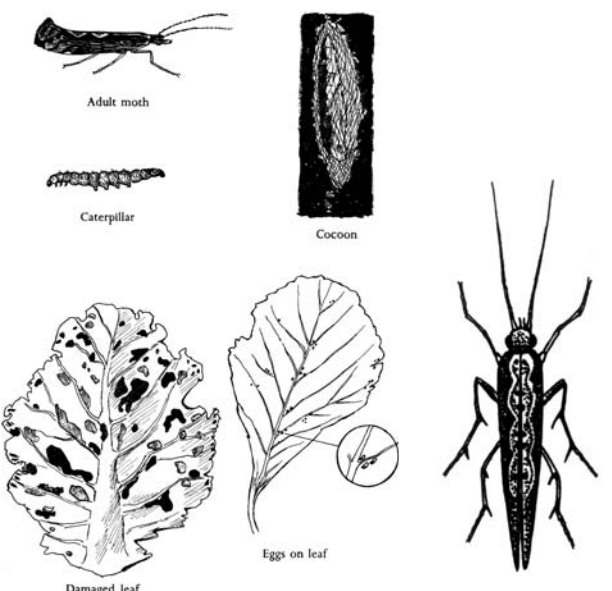
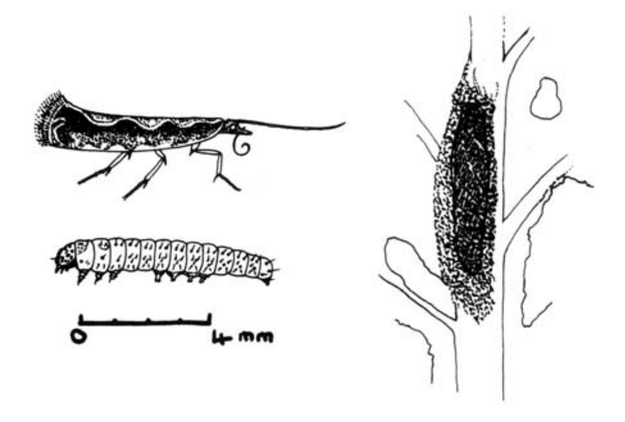


Fig. 9.248. Plutella xylostella (Diamond-back Moth); S. China



Damaged cabbage leaf





Cryptophlebia leucotreta (Meyrick)
(= *Argyroploce leucotreta* Meyrick)

Common name. False Codling Moth
Family. Tortricidae
Hosts (main). Cotton and *Citrus* spp.
(alternative). Many wild and cultivated fruits macadamia nuts are attacked including oranges, guava, wild figs, and sodom apples; maize is also an important host.
Damage. Caterpillars mine in the boll wall or in the developing seeds.
Pest status. A serious pest of *Citrus* in Africa, especially on navel oranges, and occasionally serious pest of cotton.
Life history. The eggs are flat and oval in outline, whitish, and about 0.9 mm long. They are usually laid singly on large green bolls or on the surface of the fruit, but sometimes a few are laid together overlapping like tiles. On average about eight eggs may be found on one fruit. They hatch after about 3–6 days.

The young caterpillars are whitish and spotted. Fully grown, they are about 15 mm long, pinkish with red above. The larval period lasts for 17–19 days. The young larvae wander about the fruit for some time before penetrating it. A little dark frass can be seen at the point of entry. The caterpillars normally feed on large, but not mature, bolls. The young caterpillars first mine in the walls of the bolls, but later they move into the cavity of the bolls and feed on the seeds.

Pupation takes place in the soil in a cocoon of silk and soil fragments, taking 8–12 days.

The adult is a small, brownish, night-flying moth with an average wingspan of 16 mm. The female may live for a week or more and lay 100–400 eggs.
Distribution. Africa, both tropical and southern temperate, from Ethiopia, Senegal, Ivory Coast, Togo, and Upper Volta down to S. Africa; Mauritius and Madagascar.
C. ombrodelta is the Macadamia Nut Borer of southern Africa, Australia, USA, India and china (CIE map no. A.353).
Control. No really successful economic chemical control measures are known. For cotton, a close season of at least two months is effective.

For *Citrus*, orchard sanitation is the only effective method of control. Infested fruit should be picked from the tree and collected from the ground at least twice a week.

Insecticides which show some success against this pest are DDT, dichlorvos, parathion, mevinphos, and phosphamidon.

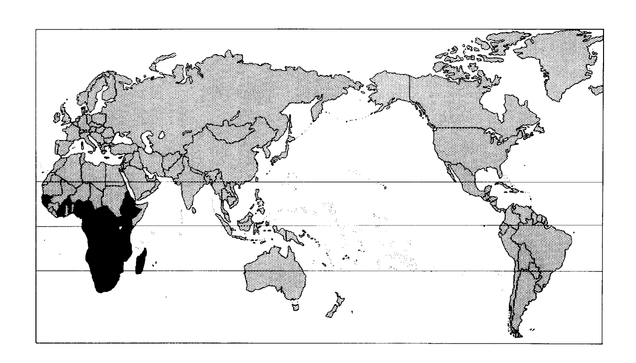
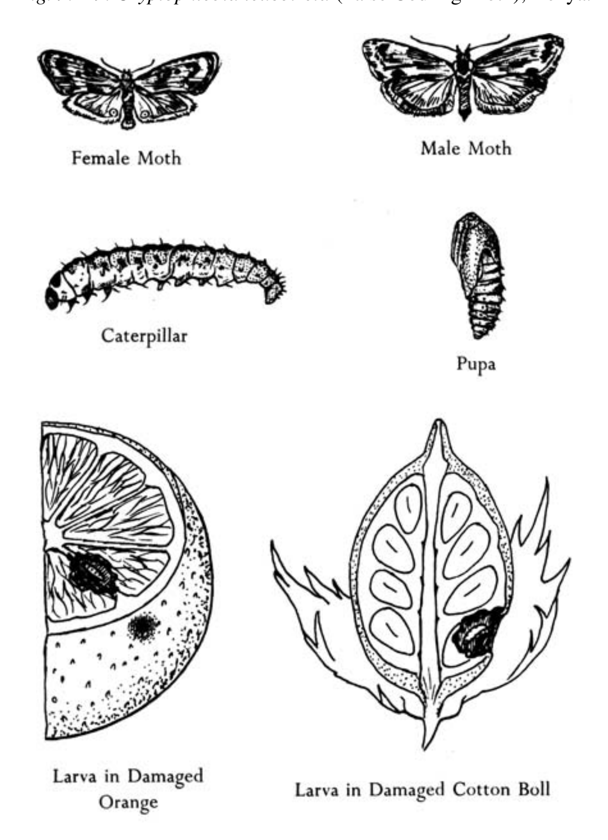


Fig. 9.249. Cryptophlebia leucotreta (False Codling Moth); Kenya.



Fruit tree tortricids (and others)

(Lepidoptera; Tortricoidea)

The present taxonomic arrangement accepted in the UK is that the superfamily Tortricoidea contains two families: the Cochylidae (= Phaloniidae), a small group, and the very large family Tortricidae. The Tortricidae now consists of two subfamilies, the Olethreutinae (containing what were formerly regarded as 11 different subfamilies) and the Tortricinae (containing three former subfamilies). In the literature there are sometimes as many as 6–8 different families/subfamilies listed for the Tortricoidea, so in some texts the taxa and the names used for this group are quite confusing, especially as the generic synonymy is extensive. The group is large and worldwide, with more than 4000 species, but more abundant in temperate regions. The adults are small dark-coloured moths with broad wings and usually crepuscular habits; most species respond to light traps and many to pheromones and sex attractants, which does enable their emergence to be monitored.

The eggs are typically small, oval and flattened, sometimes laid singly and sometimes in small groups, usually cryptically coloured, and sometimes covered with bristles or debris. The larvae are small and often pale-coloured rather slender little caterpillars (referred to in the USA as 'budworms') that usually live concealed inside folded or rolled leaves, or in shoots webbed with silk, though some bore into fruits and some bore into the stems and rootstocks of herbaceous plants. When exposed the caterpillars typically wriggle violently, often moving swiftly backwards, and fall off the plant hanging by a silken thread. This escape mechanism results in some caterpillars being accidentally transported from crop to crop (or glasshouse to glasshouse) on the clothing of workers. Some species are actually transported as first-instar larvae on their silken threads (as with young spiders) by air currents and winds. Larval coloration tends to vary considerably and in some species has been clearly demonstrated to vary according to the precise host plant inhabited and eaten.

Many species are pests of temperate fruit trees (including *Rubus*, *Vaccinium* and *Fragaria*) and these are collectively referred to as the 'fruit tree tortricids'. Many others are damaging to forest trees (oak, larches, pines, etc.) and some are very serious pests in northern forests. Some are pests of ornamentals, especially various flowers and *Rosa*, and some are important pests of both tropical and temperate legume crops (pea moths, etc.). A few species damage some herbaceous annual crops. Ecologically they are basically woodland species, and it is not surprising to find that many species feed on hazel and *Lonicera* in Europe and N. America. Some species are quite polyphagous in diet but others are confined to a single genus of host plant. On some crops the total number of species recorded is large, and so field identification may be difficult sometimes; for example the number of tortricids recorded from some popular hosts are as follows (approximately): apple, 25; *Prunus*, 25; hazel, 15; *Vaccinium*, 20; strawberry, 10.

Important pest species of Tortricoidea

Family Cochylidae (= Phaloniidae)
Aethes dilucidana (Stephens) – parsnip flowerheads; Europe.
Aethes francillana (F.) – carrot flowerhead and stem; Europe.
Cochylis hospes Wal. – (Banded Sunflower Moth) USA.
Eupoecilia ambiguella–grapevine, *Prunus*, *Ribes*; Europe.
Lorita abnormana Busck – (Chrysanthemum Flower Borer) USA.

Family Tortricidae
Acleris comariana (L. & Z.) – (Strawberry Tortrix) Holarctic.
Acleris cristana (D. & S.) – (a fruit tree tortrix) Europe, Asia, Japan.
Acleris rhombana (D. & S.) – (a fruit tree tortrix) Europe, Asia Minor, N. America.
Acleris variegana (D. & S.) – (a fruit tree tortrix) Europe, Asia, N. America.
Adoxophyes orana (F.von R.) – (Summer Fruit Tortrix) Europe, Asia, Japan.
Ancylis comptana (Froe.) – (Strawberry Leaf Roller) USA.
Archips argyrospila (Wlk.) – (Fruit Tree Leaf Roller) USA, Canada.
Archips crataegana (Hübner) – (a fruit tree tortrix) Europe, Asia, Japan.
Archips podana (Scopoli) – (Fruit Tree Tortrix) Europe, Asia (see page 401).
Archips rosana (L.) – (Rose Tortrix) polyphagous; Europe, Asia, N. America.
Archips spp. – (Apple Leaf Rollers) Japan.
Argyrotaenia citrana (Fern.) – (Orange Tortrix) USA.
Argyrotaenia juglandana (Fern.) – (Hickory Leaf Roller) USA.
Argyrotaenia pulchellana (Haw.) – (Polyphagous Leaf Roller) Europe, Asia Minor, Canada, USA.
Cacoecimorpha pronubana (Hübner) – (Carnation Leaf Roller) Europe, Asia, N. America.
Choristoneura diversana (Hübner) – (Plum Tortrix) Europe, Asia, Japan.
Choristoneura hebenstreitella (Muller) – polyphagous, Europe, Asia Minor, Japan.
Clepsis spectrana (Treit.) – (Cyclamen Tortrix) N. and C. Europe, S.E. Russia.
Cnephasia interjectana (Haw.) – (Flax Tortrix) Europe, Asia, Canada.
Cnephasia longana (Haw.) – (Omnivorous Leaf Tier) Europe, USA.
Croesia holmiana (L.) – (a fruit tree tortrix) Europe, Asia Minor.
Cryptophlebia leucotreta (Meyr.) – (False Codling Moth) Africa (CIE map no. A.352).

Cryptophlebia ombrodelta (Lower) – (Macadamia Nut Borer) Australia, USA, Africa, China, India (CIE map no. A.353).
Cydia funebrana (Treit.) – (Plum Fruit Maggot) Europe, Asia.
Cydia leucostoma (Meyr.) – (Tea Flushworm) India.
Cydia molesta (Busck) – (Oriental Fruit Moth) S. Europe, China, Japan, USA, S. America.
Cydia nigricana (F.) – (Pea Moth) Europe, Japan, Canada, USA.
Cydia pomonella (L.) – (Codling Moth) cosmopolitan.
Cydia prunivora (Walsh) – (Lesser Appleworm) USA, Canada (CIE map no. A.421).
Cydia ptychora Meyr. – (African Pea Moth) most of Africa.
Cydia pyrivora (Dan.) – (Pear Tortrix) E. Europe, W. Asia (CIE map no. A.422).
Ditula angustiorana (Haw.) – (a fruit tree tortrix) Europe, Asia Minor, Canada, USA.
Epiphyas postvittana (Wlk.) – (Light Brown Apple Moth) Europe, Australasia, Hawaii, USA.
Gretchena bolliana (Sling). – (Pecan Bud Moth) USA.
Hedya nubiferana (Haw.) – (a fruit tree tortrix) Europe.
Homona coffearia (Nietn.) – (Tea (Coffee) Tortrix) India, China, Japan, S.E. Asia, Australasia.
Laspeyresia caryana (Fitch) – (Hickory Shuckworm) USA.
Laspeyresia glycinivorella Mats. – (Soybean Pod Borer) S.E. Asia, Japan.
Lobesia botrana (Schiff.) – (European Grape Berry Moth) Europe (not UK), Japan, E. Africa.
Lozotaenia forsterana (F.) – on strawberry, *Ribes*, etc.; Europe to S.E. Siberia.
Melissopus latiferreanus (Wals.) – (Filbertworm) USA.
Merophyas divulsana (Wlk.) – (Alfalfa Leaf Tier) Australia.
Olethreutes permundana (Clemens) – (Raspberry Leaf Roller) USA.
Olethreutes spp. – (fruit tree tortricids) Europe.
Pammene rhediella (Clerck) – (Fruitlet Mining Tortrix) Europe.
Pandemis cerasana (Hubner) – (Barred Fruit Tree Tortrix) Europe.
Pandemis corylana (F.) – polyphagous; Europe, Asia, Japan.
Pandemis heparana (D.&S.) – (a fruit tree tortrix) Europe, Asia, Japan.
Ptycholoma lecheana (L.) – (a fruit tree tortrix) Europe, Asia Minor.
Rhyaciona spp. – (Pine Shoot Moths) Europe, Asia, Canada, USA.
Spilonota ocellana (D. & S.) – (Eye-spotted Bud Moth) Holarctic.
Suleima helianthana (Riley) – (Sunflower Bud Moth) USA.
Tetramoera schistaceana Snellen – (Grey Sugarcane Shoot Borer) Japan, China, S.E. Asia, Indonesia.
Tortrix dinota (Meyr.) – (Brown Tortrix) Africa.
Tortrix viridiana (L.) – (Green Tortrix) oak, blueberry, etc.; Europe, Asia Minor.

Control of fruit tree tortricids

For several of the more important species of pests there are now sex pheromones commercially available, and it has become standard practice to use ultra-violet light traps, sticky traps (and others) baited with sex attractants to monitor the emergence of the moths so as to permit precise timing of insecticide sprays. For a few species an economic threshold trap catch has been worked out, and for these species a lesser catch means that spraying is not recommended.

There are so many different species collectively referred to as ‘fruit tree tortricids’ with differing biologies and habits that it is somewhat difficult to generalize about details of control measures, so it is important to seek local advice when planning a pest control programme.

The insecticides currently regarded as ‘effective’ against a wide range of Tortricidae include the following: azinphos-methyl plus demeton-*S*-methyl sulphone, carbaryl, chlorpyrifos, demephion, dichlorvos, dimethoate, fenitrothion, formothion, heptenophos, malathion, mevinphos, oxydemeton-methyl, permethrin, phosalone, phosphamidon, thiometon, triazophos and vamidothion. Clearly some chemicals possess different qualities, and some are also effective against other pests; so the final choice of sprays depends upon several factors, one major factor being the nature of the pest complex locally. Some sprays are planned to kill the emerging adult moths, but most are aimed at the first-instar larvae hatching from the eggs. With the fruit-boring caterpillars spray timing is critical if the larvae are to be killed before they penetrate the fruits. Similarly with the legume pod borers the newly hatched larvae must be killed before they can bore into the pods.

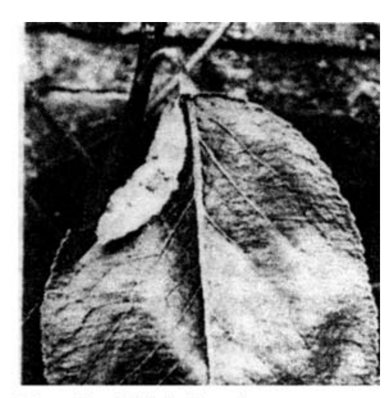
In most fruit orchards it is not possible to predict the level of attack likely in any one year, so often the decision to apply control measures is based empirically on the previous history.

Fig. 9.250. Tortricid damage to fruit trees.

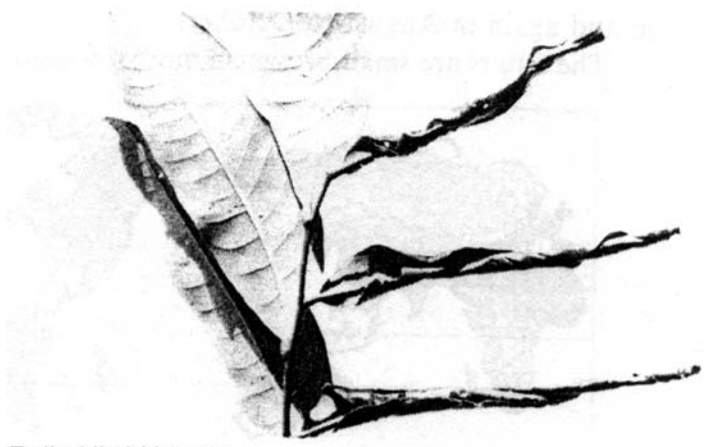




Apple leaves webbed and eaten



Pear leaf folded and cut



Rolled litchi leaves

Cydia pomonella (L.)

Common name. Codling Moth
Family. Tortricidae
Hosts (main). Apple, pear
(alternative). Peach, quince, walnut, *Prunus* spp.
Damage. The feeding caterpillars tunnel inside ripening fruits, making a small entrance hole and a larger exit. The entrance hole has a surrounding dark red discoloration. Most attacked fruits fall prematurely.
Pest status. Possibly the single most important pest of apples worldwide; often most serious in gardens. Largest populations often unpredictable, but sometimes correlated with particularly warm and sunny conditions (optimum conditions recorded as 21–3°C).
Life history. Eggs are laid singly, on foliage or fruits; they are flat, circular and translucent (1 mm diameter), and difficult to find; each female lays about 40–50 eggs, over a period from mid-June to early August in the UK. Hatching requires about 10–14 days usually.

Young larvae immediately search for a suitable entry point into the fruit, usually at the 'eye' or the side of the fruit. They bore into the flesh and feed, often finally tunnelling the core. The caterpillars are white when young but in the last instar turn pink (with a dark head) when they are about 12 mm long. Some larvae damage a second apple before ceasing to feed; larval development takes some 21–35 days. Full-grown larvae leave the fruit and spin cocoons under loose bark, or in crevices, and here they overwinter, pupating the following spring when pupation takes 14–28 days. In the UK there is usually just one generation annually, but in N. America there are two; in both areas in a warm season there may be a small additional generation in the autumn.

The adult is a small moth, 6–8 mm long, with wingspan 12–14 mm, with dark greyish wings having a copper-coloured spot distally; hindwings pale grey.
Distribution. Recorded from virtually all the apple-growing regions of the world; throughout Europe, Asia, Australia, New Zealand, S. Africa, Canada, USA and S. America (CIE map no. A.9).
Control. Where there is a recent history of damage it is usually necessary to use insecticides, but in many areas there is a tortrix complex to control, so choice of insecticide and precise timing may be governed by the nature of the local pest complex (see page). Codling Moth pheromone/sticky traps are commercially available in most countries now.

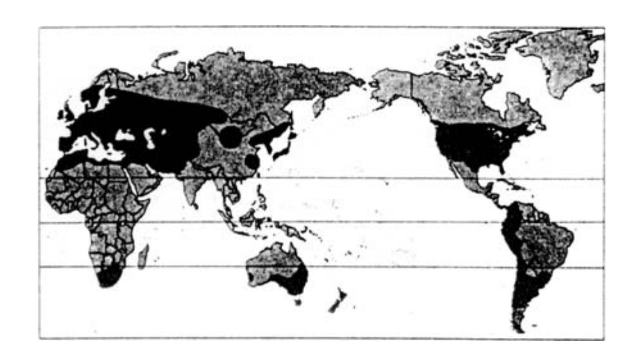
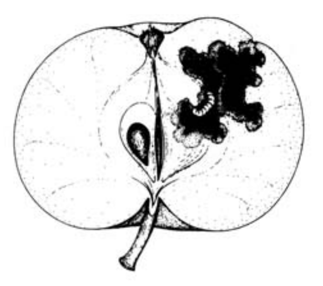
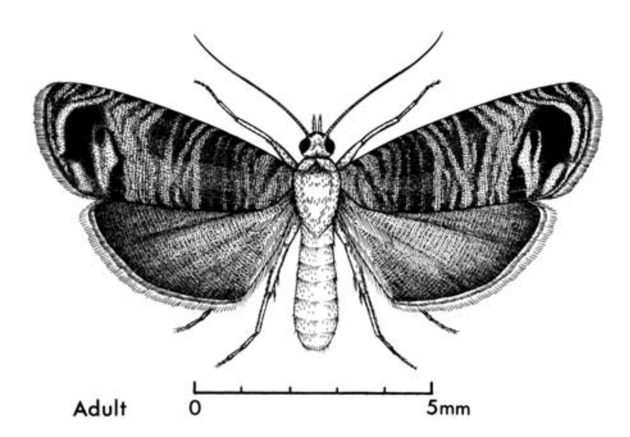


Fig. 9.251. Cydia pomonella (Codling Moth); Cambridge, UK.





Eucosma nereidopa Meyr.
(= *E. phylloseia* Meyr.)

Common name. Coffee Tip Borer
Family. Tortricidae
Hosts (main). Coffee (*arabica*).
(alternative). Not known.
Damage. The larvae bore into terminal shoots, killing the shoots and tips of branches. Sometimes berries are similarly bored. The caterpillar usually bores into the stem half-way between two nodes near the top of a thick, succulent sucker. A slight swelling indicates the point of entry, and the tip wilts rapidly. One larva may destroy two or three shoot tips.
Pest status. A sporadically serious pest of high altitude *arabica* coffee in E. Africa; populations are sometimes very high and the damage extensive.
Life history. The eggs are flat, circular, white, and are laid singly or in small groups in slight grooves near the tip of a sucker or on the side of a berry. Hatching takes about 14 days.

The caterpillar is dark brown and bores into the plant after a few hours. Fully grown, the caterpillar is about 12 mm long.

Pupation takes place in a chamber which the caterpillar makes by enlarging a natural crevice in the rough bark near ground level. The pupal period lasts about 36 days.

The adult moth is pale and dark grey and about 8 mm long. During daylight hours they rest on the trunks of coffee and shade trees near ground level. The pre-oviposition period is four or more days.
Distribution. E. Africa.
Control. Control consists of killing the adult moths before they are able to lay their eggs. When a sufficient number of moths are observed on a selection of shade trees (ten per block of infested coffee), that is an average of more than five moths per shade tree before the suckers have been thinned out, or more than one moth per shade tree after sucker thinning, spray the shade tree trunks with fenitrothion. Supplementary sprays will be required.

This moth does sometimes occur in unshaded coffee plantations, and work is still in progress to devise adequate control measures.

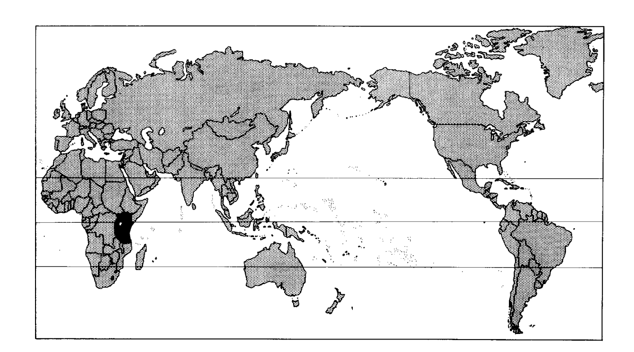
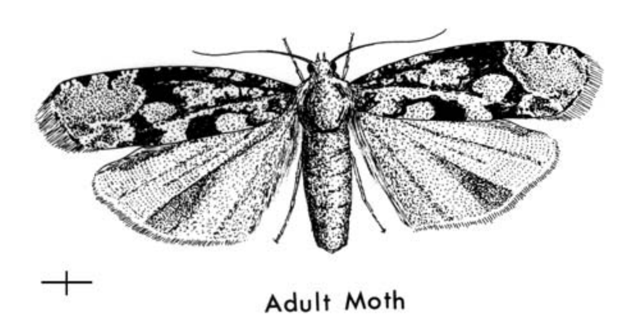


Fig. 9.252. Eucosma nereidopa (Coffee Tip Borer); Kenya.





Grapholita molesta (L.)

Common name. Oriental Fruit Moth
Family. Tortricidae
Hosts (main). Peach, and other stone fruits.
(alternative). Many other fruit trees, including apple.
Damage. The caterpillars damage both twigs and fruits. Early in the season the larvae bore into the tips of soft young shoots and cause them to wilt and die. Later, when the shoots have hardened and the fruits ripen, most of the caterpillars bore into the fruits. Shoot destruction causes bushy secondary growth.
Pest status. A serious pest of peaches and other stone fruits in various countries; of lesser importance on many other deciduous fruit trees.
Life history. Eggs are laid on the leaves and twigs (and later on fruits) just about flowering time.

The first caterpillars bore into soft green shoots and feed internally, but later generations tunnel into ripening fruits (like Codling Moth). Full-grown larvae are white with a pink tinge, 8–10 mm long, with a characteristic black, dorsal comb-like structure on the last abdominal segment bearing five teeth. Larval development can be completed in only two weeks; they leave the tunnels in order to pupate; those leaving fruits emerge from a sizeable hole that later exudes sap. They pupate inside silken cocoons stuck onto a solid substrate (the tree or ground). Pupation takes about ten days. The final-generation larvae over-winter in the pupal cocoons, and pupate in the spring.

The adults are small dark moths with distinctive costal strigulae; wingspan is about 12 mm. First-generation adults emerge at peach flowering time.

In southern USA the life-cycle is completed in about one month, and there are typically 4–5 generations annually.
Distribution. Found in southern Europe, China and Japan; now in S. Australia, S. America, Mauritius, the USA and Canada (CIE map no. A.8). It was introduced into the USA from Japan in 1913.
Control. In parts of N. America a high level of control is achieved using natural parasites, *Trichogramma minutum* on the eggs and several braconids on the larvae; natural populations are usually supplemented by reared releases.

When insecticidal sprays are needed the chemicals mentioned on page 394 are generally effective, but it is usual to apply 3–5 sprays through the season.

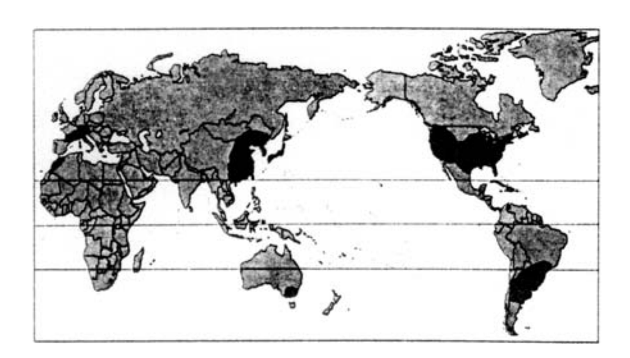
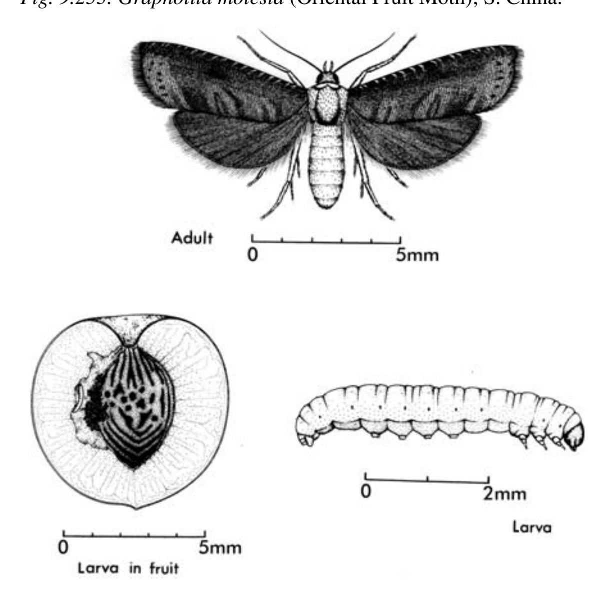


Fig. 9.253. Grapholita molesta (Oriental Fruit Moth); S. China.



Homona coffearia (Nietn.)

Common name. Tea (Coffee) Tortrix (Tea Flushworm)
Family. Tortricidae
Hosts (main). Tea
(alternative). Coffee, *Acacia, Syzygium*, and indigo.
Damage. The feeding larvae roll or fold leaves longitudinally and feed within the roll, moving periodically to new sites and webbing new leaves.
Pest status. As a pest of tea this species is most important in Sri Lanka, but is of regular occurrence in the other regions indicated.
Life history. Eggs are laid in small clusters in batches of 100–150, on the flush leaves, usually on the dorsal surface. The caterpillars are slender and green with a dark dorsal shield and mature at about 20–25 mm. Pupation takes place within the folded leaf, and requires from 6–14 days, according to temperature.

The adult moth is a typical tortricid in appearance with curved wings and prominent wingtips, brownish-yellow in colour. Wingspan is about 24–28 mm.

In India one generation takes from 36–44 days, but elsewhere up to 60–70 days.
Distribution. S. India, Sri Lanka, Bangladesh, parts of S.E. Asia and up to China, and Japan. Also West Irian, Papua New Guinea and part of the Queensland coastal area (CIE map no. A330).
Control. In Sri Lanka the severe outbreaks of this pest led to consideration of biological control, and the larval parasite *Macrocentrus homonae* (Braconidae) was imported from Java where it naturally controls the pest. *Macrocentrus* has proved to be very successful and the level of parasitism on the island is high, so the tortrix is no longer regarded as a very serious pest locally. The two main reasons for the parasite's success are possibly its short breeding cycle of seven weeks as opposed to the ten weeks of the host and the fact that it is polyembryonic, and each egg may give rise to as many as 30 larvae inside the host.

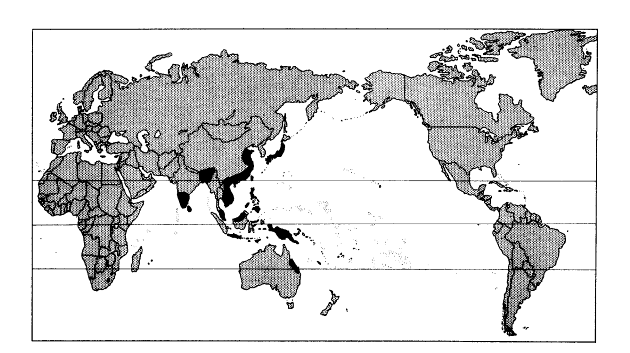
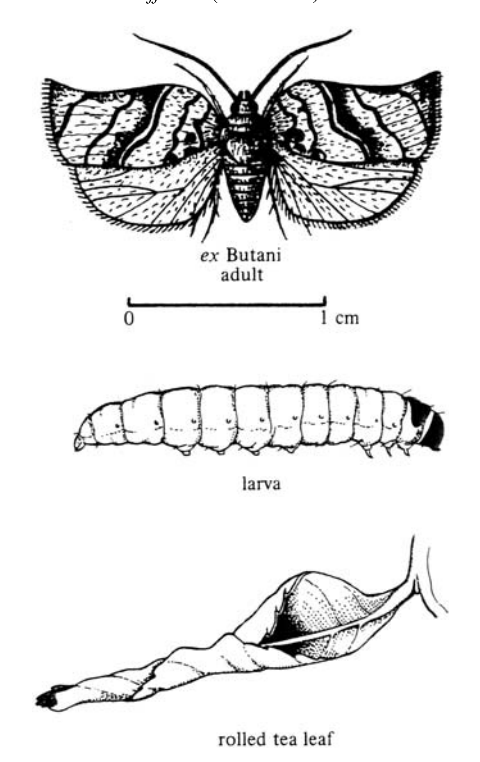


Fig. 9.254. Homona coffearia (Tea Tortrix).



Pectinophora gossypiella (Saunders)
(= *Platyedra gossypiella* (Saund.))

Common name. Pink Bollworm
Family. Gelechiidae
Hosts (main). Cotton
(alternative). *Hibiscus* and other Malvaceae, but only cotton can support a large infestation.
Damage. The entry hole of the caterpillar into a large green boll is almost invisible. If the boll is opened, however, the red and white caterpillar can be found, especially inside the developing seeds. Damaged bolls fail to open completely and often have secondary rots where the caterpillar has been feeding.
Pest status. Potentially very serious in all cotton-growing areas, but control can be achieved by enforcement of a close season.
Life history. The egg is oval, about 0.55 mm long; laid singly or in small groups, on or near a bud or boll. Hatching takes 4–6 days.

Full-grown larvae are 10–12 mm long, white with a double red band on the upper part of each segment. There are four larval instars, the total larval period lasting 14–23 days but the larvae can enter diapause. Caterpillars feed on flower buds or young bolls and cause shedding. This is a late species and does most damage to large green bolls; the small larva enters a boll near the base and bores into a developing seed. The mature larva leaves the boll through a neat circular hole about 2 mm in diameter, drops to the ground and pupates in the litter. Pupation takes place inside a loose cocoon. The pupa is brown, 7–10 mm long and about 2.5 mm broad. Pupation takes 12–14 days.

The adult is a small brown, inconspicuous moth of wingspan 15–20 mm; nocturnal in habits. After a pre-oviposition period of about four days, it may live a further ten days and lay about 300 eggs.
Distribution. Completely pantropical in distribution, including the subtropical regions (CIE map no. A13).
Control. In some areas a mixture of DDT and endrin were recommended, or carbaryl, trichlorphon and azinphos-methyl, and sprays are applied at weekly intervals. Larvae are difficult to kill as they usually bore directly into the boll. So control aims at killing the adult moths.

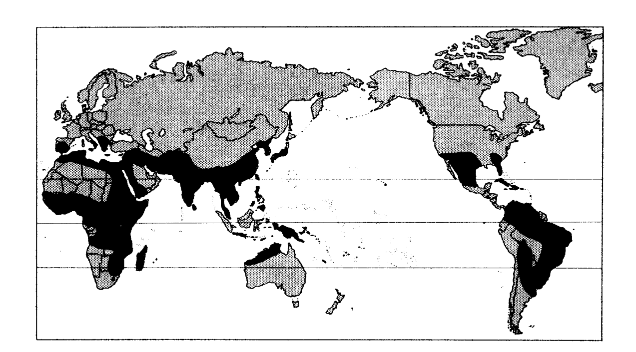
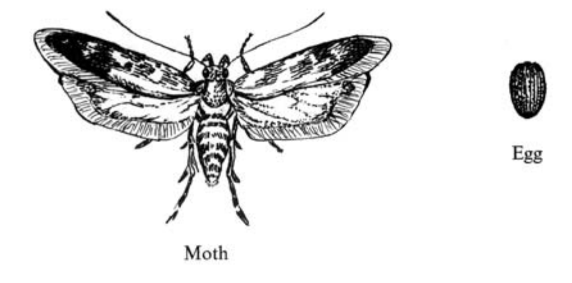
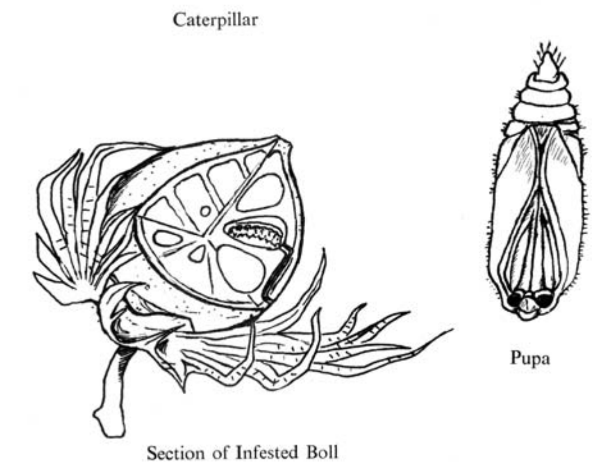


Fig. 9.255. Pectinophora gossypiella (Pink Bollworm); Kenya.







Phthorimaea operculella (Zeller)
(= *Gnorimoschema operculella* (Zeller))

Common name. Potato Tuber Moth
Family. Gelechiidae
Hosts (main). Potato and Tobacco
(alternative). tomato, eggplant, and other Solanaceae, and *Beta vulgaris*.
Damage. The leaves have silver blotches caused by the young larvae mining in the leaves. Leaf veins, petioles and stems are tunnelled, followed by wilting of the plants. Eventually the tubers are bored by the larger caterpillars, and they often become infected with fungi or bacteria.
Pest status. An important pest of potato in warmer countries. Infestations arising initially in the field and continuing during storage of the tubers. There is a serious risk of transportation from country to country through infested tubers.
Life history. The egg is minute and oval, 0.5 × 0.4 mm, and yellow. Eggs are laid singly on the underside of the leaf, or on tubers (usually in storage) near the eye or on a sprout. Each female lays about 150–250 eggs. The eggs on the leaves hatch in 3–15 days and the first instar larvae bore into the leaf, where they make mines. The caterpillars are pale greenish. They gradually eat their way into the leaf veins and into the petioles, then gradually down the stem and sometimes into the tuber. The full-grown caterpillar is 9–11 mm long. The larval period lasts for 9–33 days.

Pupation takes place in a cocoon in the surface litter or in the tuber, and takes 6–26 days.

The adult is a small moth with narrow fringed wings; the forewings are grey-brown with dark spots, and the hindwings are dirty white. The wingspan is about 15 mm. The moths are very short-lived.

One generation takes some 3–4 weeks, and there can be up to 12 generations per year, but development is very dependent upon temperature.
Distribution. Almost completely cosmopolitan in distribution, but with limited records from Asia and none from W. Africa (CIE map no. A10).
Control. Effective insecticides are DDT, dicrotophos, dimethoate, and parathion, all as sprays. As a preventative measure sprays should be applied every 14 days after the first mines are found in the leaves. In stores permethrin, deltamethrin, phosphine and phenthoate all give good control. In Egypt pheromone traps in field crops gave good control.

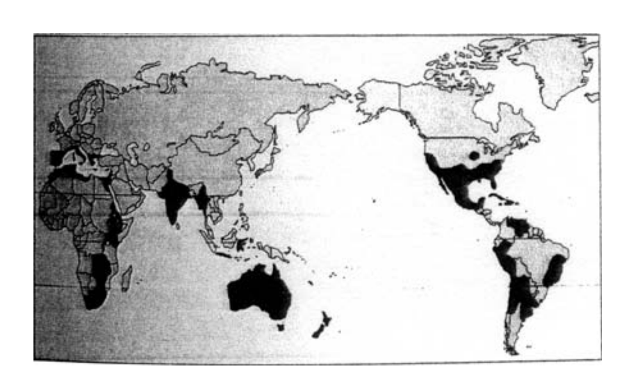
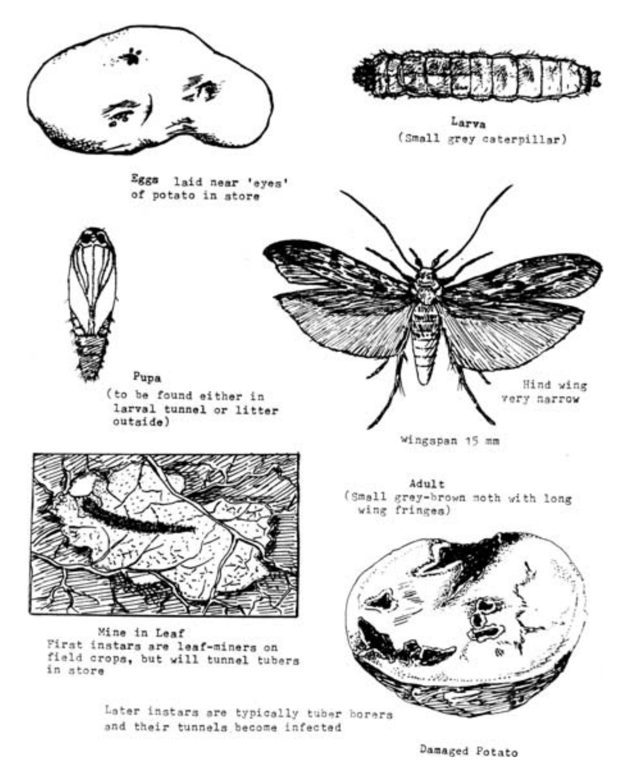


Fig. 9.256. Phthorimaea operculella (Potato Tuber Moth); Kenya.



Sitotroga cerealella (Ol.)

Common name. Angoumois Grain Moth
Family. Gelechiidae
Hosts (main). Maize and wheat barley, both in the field and in grain stores.

(alternative). Sorghum and other stored grains, and dried fruit.

Damage. Infested grains with mature larvae or pupae can be recognized by the presence of a very small window in the grain. On emergence the adult pushes its way through this small circular window and the 'trap door' is left hinged to the grain, which is characteristic of this pest. Field infestations of maize, wheat and barley are common.

Pest status. A serious pest in many parts of the world. The infestation by this moth starts in the field and may reach serious levels, before being translocated to the grain stores.

Life history. The eggs are ovoid and pinkish and are laid on the surface of the grains; 200/♀.

The larvae are elongated, dirty white, about 8 mm long. The body is covered with fine setae. The larvae bore their way into the grain and feed there; before pupation they form a channel to the surface, leaving the seed coat intact (19 days at 30°C & 80% RH).

The pupa, which is dark brown, is enclosed in a delicate cocoon, inside the grain (5 days at 30°C).

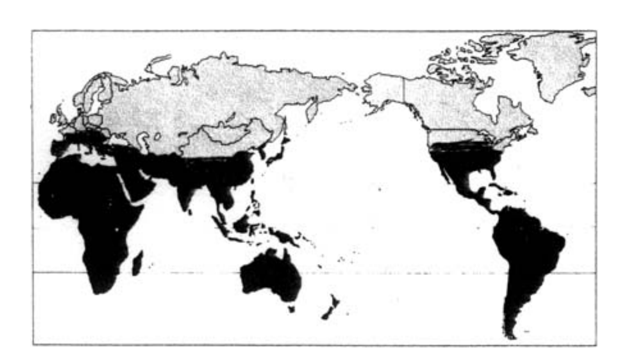
The adult is a small, straw-coloured moth about 7 mm long (with wings folded); the wings are 15 mm across when open and the hindwings have a long fringe. One female can lay about 200 eggs. The adults are short-lived. (5–12 days).

The life-cycle from egg to adult moth takes about five weeks at 30°C & 80.

Distribution. Cosmopolitan in the warmer parts of the world.

Control. Dust the maize cobs with lindane dust, and also the surface of the wheat bags; as an alternative malathion dust can be used.

Fumigation with materials such as methyl bromide should only be carried out by approved operators.



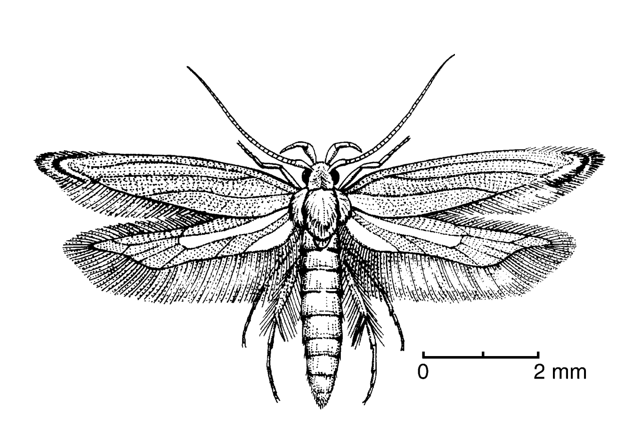
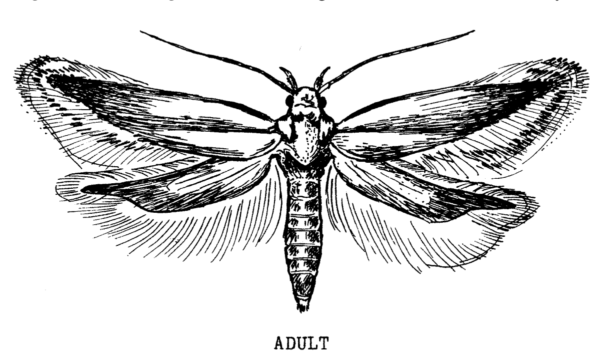
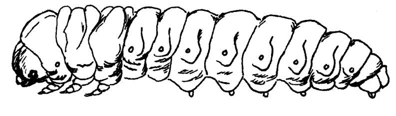
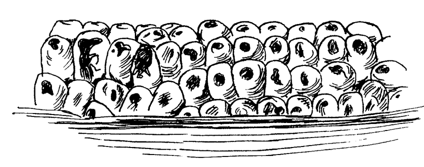
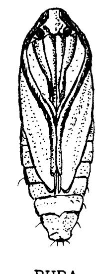


Fig. 9.257. Sitotroga cerealella (Angoumois Grain Moth.); Kenya.









Eulophonotus myrmeleon Feldr.
(= *Engyophlebus obesus* Karsh)

Common name. Cocoa Stem Borer
Family. Cossidae
Hosts (main). Cocoa

(alternative). Coffee, cola, *Populus*, and *Combretum* spp.

Damage. Extensive tunnels are bored in the branches and main trunk by the larvae; sometimes even roots are bored. Trees less than one year old are rarely attacked. The upper parts of the tree may die.

Pest status. They are usually only found in small numbers, and often are more common in plantations frequently treated with insecticides. In such plantations infestation rates of more than 5% may occur. However, this is not generally a serious pest in most parts.

Life history. The egg period lasts about 12–13 days, and there may be 1500 eggs laid by one female. The eggs are laid in crevices in the bark.

The larval period is usually at least 12 weeks, and the pupal period another 20 days.

The adult male is 20–28 mm across the wings, which are almost clear and devoid of scales. The female is 45–50 mm in wingspan, with sooty-brown wings, the forewing having many small clear areas without scales.

Distribution. W. and E. Africa only.

Control. Control is not often required, and is incidentally difficult to achieve. The insecticides which are sometimes used are DDT, dieldrin, endrin, and phosphamidon, and they are sprayed on the bark of the trees at the times when egg-laying is expected.

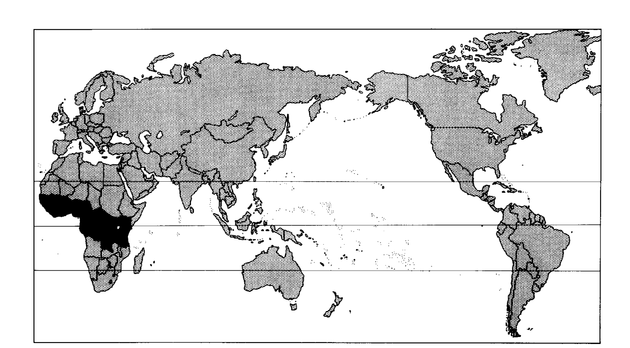
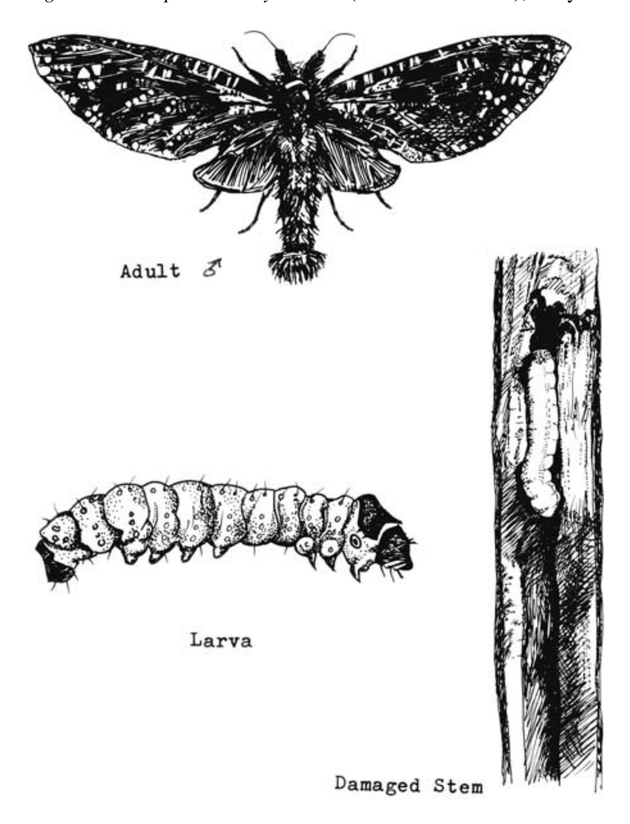


Fig. 9.258. Eulophonotus myrmeleon (Cocoa Stem Borer); Kenya.



Xyleutes capensis (Wlk.)

Common name. Castor Stem Borer
Family. Cossidae
Hosts (main). Castor
(alternative). *Cassia* spp.
Damage. The larvae bore in branches or trunks of the castor tree causing the death of the branch, which often breaks at the level of the tunnel. Prior to the death of the branch the foliage withers and the leaves die and turn brown. Sometimes there may be sap exudation from the frass holes.
Pest status. A locally important pest of castor in E. Africa, but cossids generally are widely occurring throughout the world in a wide range of host trees.
Life history. Details of this pest are not known, but in general female Cossidae lay their eggs in cracks in the bark; each female laying several hundred eggs. One species *X. durvillei* in Australia lays 18,000 eggs.

The caterpillars immediately start to bore into the branches, and will probably spend many months as larvae; sometimes cossid larvae live for one or two years before pupation.

Pupation typically occurs in a hollowed-out cell just below the surface of the bark, and during the process of emergence the old pupal exuvium is left with the anterior part projecting out of the bark.

The adult is a large, stout-bodied moth about 35 mm long and with a wingspan of 70–80 mm.
Distribution. E. Africa.
Six species of Xyleutes bore the branches and trunks of coffee in W. Africa, India, and the W. Indies. *Xyleutes* is best represented in Australia with 69 species, many boring in *Acacia* and *Eucalyptus* trees. Several species are important pests of teak and other forest trees in S.E.Asia.
Control. Control measures are seldom required on the whole, and are even less frequently successful, for once the larva is inside the branch it is quite safe from attack.

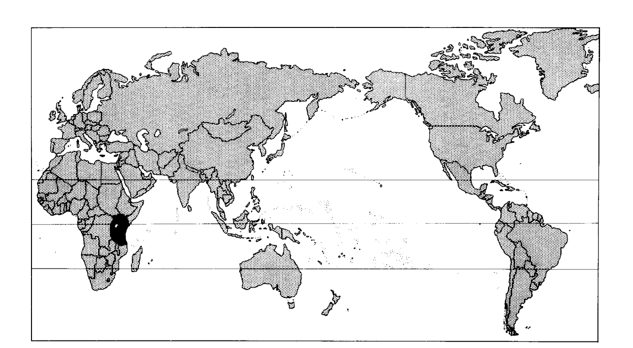
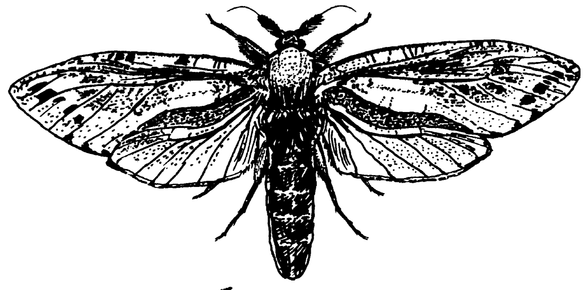
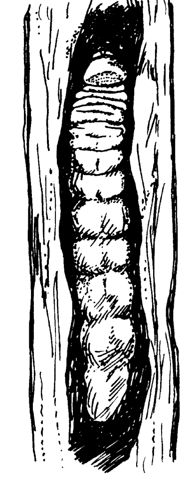


Fig. 9.259. Xyleutes capensis (Castor Stem Borer); Kenya.





Zeuzera coffeae (Nietn.)

Common name. Red Coffee Borer (Red Branch Borer)
Family. Cossidae
Hosts (main). Coffee

(alternative). *Citrus*, cocoa, tea, guava kapok, cotton forest trees such as teak, mahogany, sandalwood, various ornamental trees and shrubs, and wild trees.

Damage. The larva tunnels along branches (down the centre) and in trunks of both woody shrubs and trees, usually killing the branch distally.

Pest status. This polyphagous pest is widespread in the Orient, and is quite a serious pest on many different crop plants from time to time.

Life history. Eggs are usually laid single in crevices in the bark, and the young larvae, after hatching, bore straight into the branches. The larvae are stout-bodied and dark reddish in colour with a black head, prothorax and anal shield. They bore a cylindrical tunnel along the branch and periodically make bore holes to the surface out of which reddish brown frass (mostly faeces) is extruded. Pupation takes place in a cocoon made of silk and wood particles just underneath the bark. After emergence of the adult moth the old pupal exuvium is left protruding from the emergence hole (this is characteristic of all Cossidae).

In cooler regions *Zeuzera* larvae require 2–3 years for development, but in the tropics they will develop within a year, and in some places there might even be two generations per year, but this is uncertain.

The adults are striking moths, white in colour with black spots, though the abdomen is usually grey. The female is distinctly larger with a wingspan of about 5 cm and the male about 4 cm. The adults fly to lights at night and are easily caught in light traps.

Distribution. From India through to S. China and throughout most of S.E. Asia, including the Philippines, West Irian and Papua New Guinea (CIE map no. A313).

Several other closely related species occur throughout this region on a wide range of woody hosts.

Control. Caterpillars can be killed in their tunnels by pushing a springy wire down the hole, or by introducing an insecticide into the tunnel and then blocking the holes. Paradichlorobenzene, BHC and carbon disulphide have proved successful in this manner, with the hole being sealed with clay or putty. Chemical control by foliar sprays is generally not successful against this pest. In Sabah this was a serious pest on cocoa and most insecticidal treatments were not successful. Conway (1972*a*) reported that levels of larval parasitism were very high, and his final recommendation was to avoid the use of any contact insecticides whatsoever; the natural parasites subsequently controlled the pest population quite adequately.

It is generally recommended that infested branches be cut off and removed, but if there is a locally high rate of larval parasitism the cut branches should be left within the plantation to allow parasite survival.

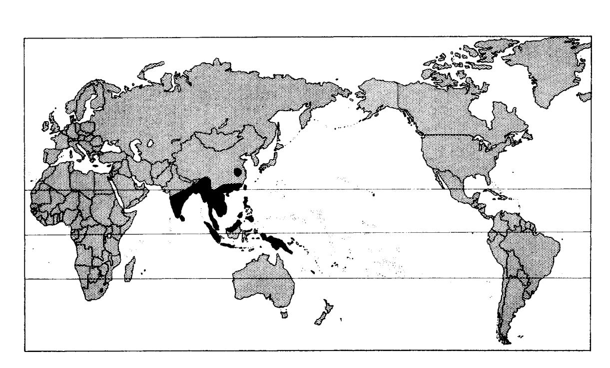
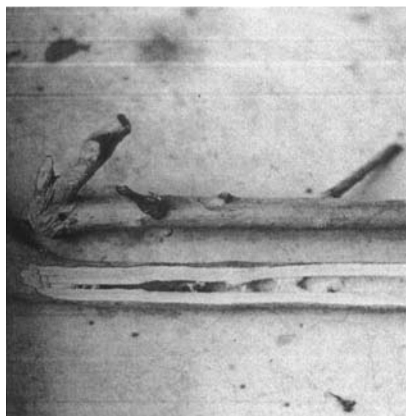
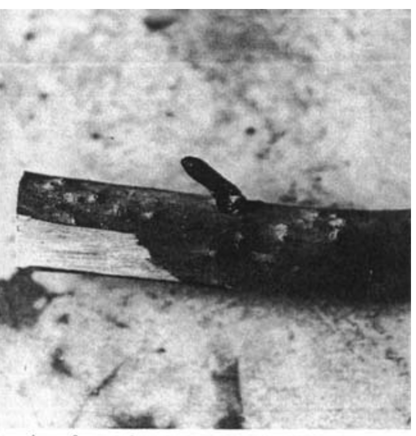


Fig. 9.260. Adult *Zeuzera coffeae* (Red Coffee Borer); S. China.





larval damage in woody stem



exuvium of pupa after emergence

Indarbela spp.

Common name. Wood-borer Moths
Family. Metarbelidae
Hosts. A polyphagous pest found on many different species of trees and woody shrubs; recorded from *Citrus*, guava, litchi, loquat, mango, mulberry, *Ficus*, jack-fruit, *Acacia*, and many other plants.
Damage. The larvae bore into the trunk or branches, usually at forks or angles, to a depth of some 15–25 cm. This deep hole is the refuge of the larva during the day (and later for pupation) and at night it emerges and eats the bark of the tree in the immediate vicinity of the hole; the feeding area is covered with a web of silk and frass. Small trees are easily ring-barked by this pest and die. If enough bark is eaten away, even large trees are distrubed by the interrupted sap flow and may fail to flush.
Pest status. This family of wood-boring moths is confined to the tropics, where several species are recorded, with different distributions on a wide range of host trees and shrubs. In most situations they are really minor pests, but are quite frequently encountered.

Life history. Eggs are laid, usually singly, in cracks in the tree bark, and the young caterpillar bores into the tree. There is only one larva to each tunnel, but in heavy infestations there may be 10–30 larvae per tree. The feeding larva eats the bark and enough of the sapwood underneath to interfere with sap flow in the phloem system. Pupation takes place within the deep tunnel, and after emergence of the adult the old pupal exuvium is left projecting out of the tunnel (as with the Cossidae).

The adult moth is a creamy white colour, with brown markings on the forewings, about 2 cm in body length and 4 cm in wingspan; the body is usually rather elongate.

There is usually only one generation per year; in S. China adults emerge in the spring.
Distribution. At present recorded information comes from India, mainland S.E. Asia and S. China. Several species of *Indarbela* are recorded as pests of many different trees in both Africa and Asia.
Control. Poking a wire down the tunnel will kill individual larvae in situ, or injection of DDT, BHC, endrin, carbon disulphide, paradichlorobenzene or kerosene into the tunnel, and sealing it with clay or will also kill the larvae.

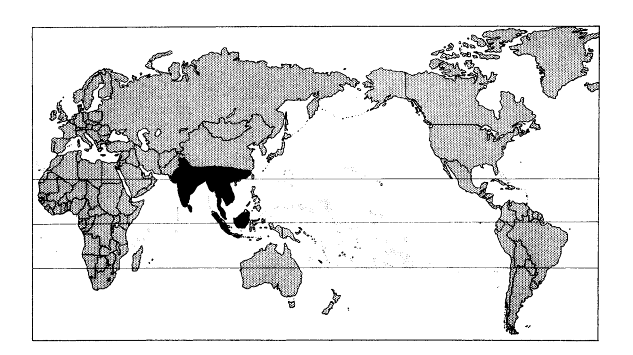
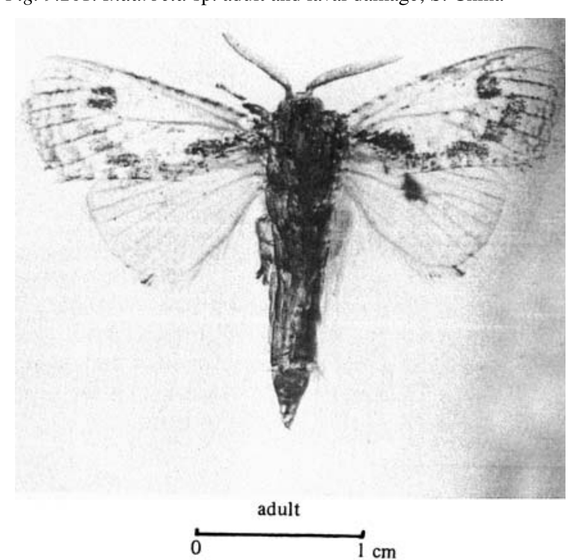


Fig. 9.261. Indarbela sp. adult and laval damage; S. China







Niphadolepis alianta Karsch

Common name. Jelly Grub
Family. Limacodidae (= Cochlidiidae)
Hosts (main). Coffee (*arabica*).

(alternative). Castor and tea are recorded as alternative hosts and these caterpillars can probably feed on a wide range of other plants.

Damage. The young caterpillars feed on the undersides of leaves; the feeding areas are small and circular and everything except the upper epidermis is eaten. Later this dies and falls out leaving small 'shot-holes' in the leaf. When about half-grown the larvae feed at the leaf edge, eating right through it and leaving a jagged edge. Fully hardened leaves are preferred as food.

Pest status. A fairly common, but unimportant, pest in eastern Africa on coffee and tea.

Life history. Eggs are white and scale-like; laid singly on either side of the leaf. On hatching, the shell collapses and remains as a transparent, flat, white speck on the leaf.

The larva is a slug-like caterpillar, whitish with a tinge of green, and is fully grown after 6–8 weeks when it is about 14 mm long.

The mature caterpillar spins a cocoon of white silk usually between two leaves or in the fold of a single leaf. The cocoon is 14–20 mm long, and the pupal period is from three weeks to much longer.

The adult moth is very rarely seen in the field. It is golden brown in colour with darker brown patches on the forewings. The wingspan is about 25 mm.

Distribution. Only found in Africa; in Malawi, Tanzania, and Kenya. *N. punctata* Her. is also found on coffee in Tanzania.

Control. Chemical control can be achieved with the use of either fenitrothion or fenthion sprays; the amount of spray being used is dependent upon the extent of the leaf cover.

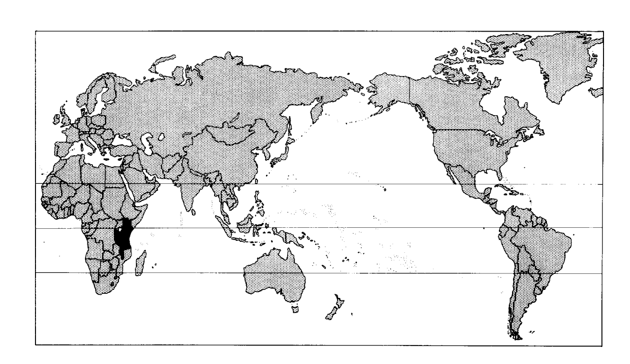
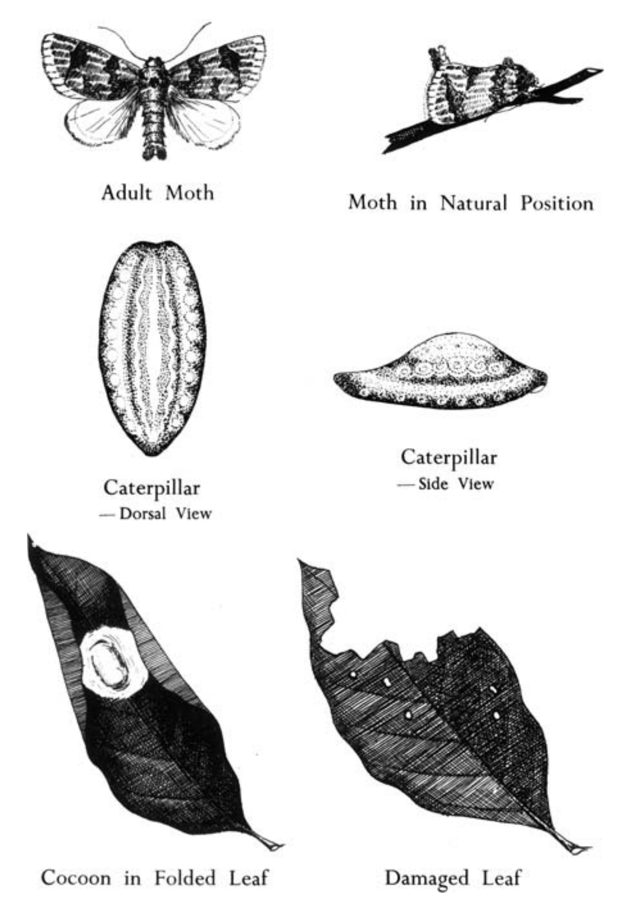


Fig. 9.262. Niphadolepis alianta (Jelly Grub); Kenya.



Parasa lepida Cram.
(= Latoia lepida (Cram.))

Common name. Blue-striped Nettle-grub
Family. Limacodidae (= Cochlidiidae)
Hosts. No clear-cut pattern of host specificity; recorded from coconut, *Citrus*, cocoa, coffee, banana, rice, tea, mango, castor, pomegranate, rose, ornamentals.
Damage. The larvae defoliate the host plants, as well as having urticating body spines.
Pest status. Usually a minor pest on many different crops, but sporadically serious, especially in India.
Life history. Eggs are laid in batches of 20–30 underneath leaves, and are shiny and rather flat. Hatching occurs after 6–7 days, and larval development takes about 40 days, at which time the caterpillar measures some 25 mm. The caterpillar bears rows of fleshy protuberances each carrying a series of sharp spines; ventrally it is quite flat and fleshy and the legs are quite indistinct. The body is green in colour with blue stripes running longitudinally. The spines on the scoli are sharp and have urticating properties which makes them a nuisance when encountered in the crop by field workers. Pupation takes place in a round hard cocoon usually stuck on to the bark of the tree, and takes about three weeks; the whole life-cycle takes about three weeks in India.

The adult moth is stout-bodied, about 15 mm in length and with a wingspan of 30–35 mm. The forewings are coloured green, with brown basal and distal portions, and hindwings pale brown.
Distribution. Most abundant in India and throughout S.E. Asia to S. China, Philippines, West Irian and Japan. The name *P. 'lepida'* apparently contains a (CIE map no. A363). revised complex of several species.
Control. Spraying with DDT, BHC, and parathion have proved to be successful, in the past.

Fenitrothion, fenthion and permethria will kill the caterpillars but should only be used on serious infestations so as to minimize the kill of natural enemies.

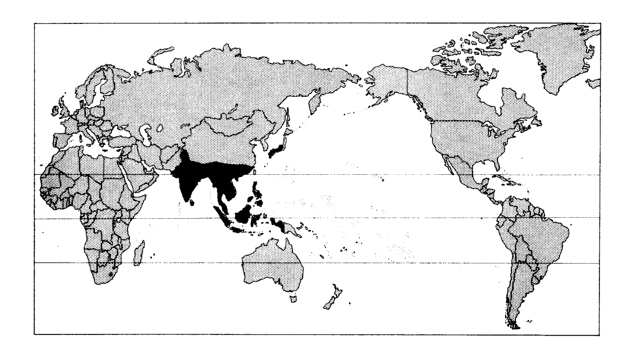


Fig. 9.263. Parasa lepida (Blue-striped Nettle-grub); S. China adult and larva.





Parasa vivida (Wlk.)
(= *Latoia vivida* (Wlk.))

Common name. Stinging Caterpillar
Family. Limacodidae (= Cochlidiidae)
Hosts (main). Coffee (*arabica*).

(alternative). Various Rubiaceae, and cocoa, groundnut, sweet potato, castor, tea and cotton.

Damage. The young caterpillars feed together on the underside of a leaf. They make small irregular pits, eating everything except the upper epidermis. The older caterpillars feed at the leaf edge, eating right through it and leaving a jagged edge.

Pest status. Usually only a minor pest of *arabica* coffee, but occasional serious outbreaks occur.

Life history. The eggs are greenish-yellow, and are laid in small batches, overlapping like tiles, on the underside of leaves. They hatch in about ten days.

The larva is an attractively coloured caterpillar, mainly white when young but green when older. It is covered with finger-like projections which bear stinging (urticating) hairs. The young caterpillars feed together on the underside of a leaf. The older caterpillar is solitary and feeds at the edge of the leaf. The larval period lasts about 40 days.

Pupation takes place in an oval, white cocoon which is about 14 mm long and made of tough silk. The cocoon is stuck to the branch of a tree. After spinning the cocoon, the pre-pupa often goes into a resting stage and does not actually pupate for many months. Combined pre-pupal and pupal stages last for as long as 134 days in Kenya.

The adult moth has green forewings edged with brown and yellow hindwings. The wingspan is 30 mm.

Distribution. This pest is confined to Africa; occurring in Ivory Coast, E. Africa, Malawi, Sierra Leone, Zimbabwe, Zaïre, Nigeria and Mozambique.

Control. Chemical control can be achieved with fenitrothion or fenthion as aqueous sprays, the quantity of spray depending upon the amount of leaf cover.

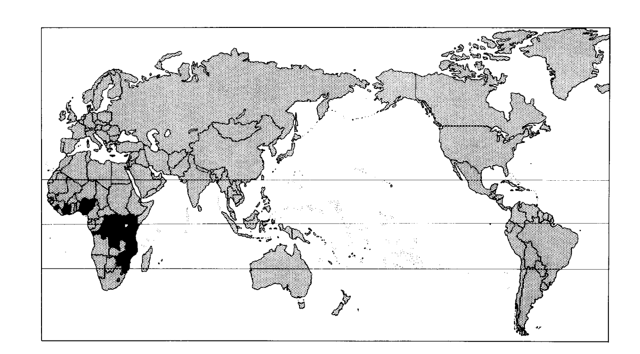
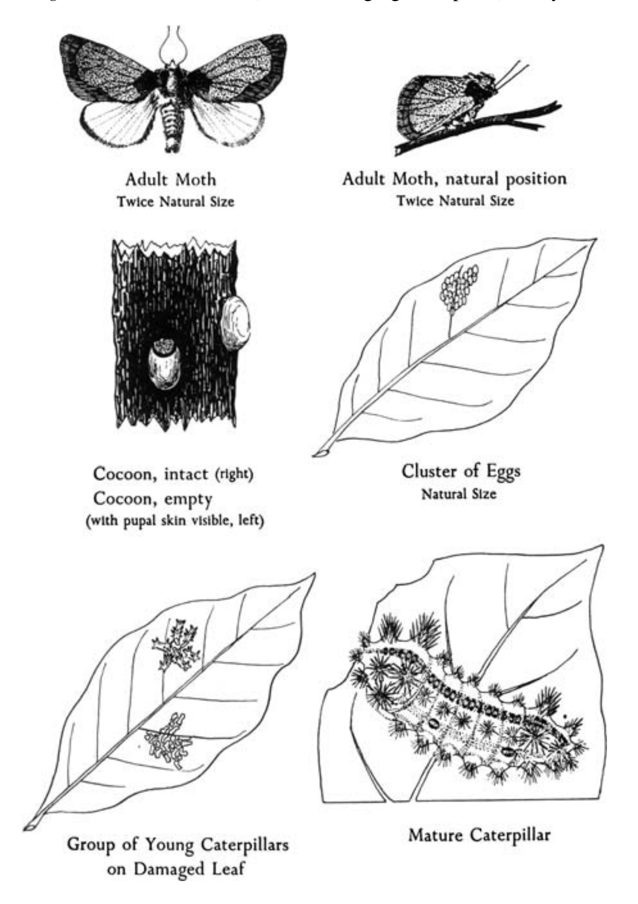


Fig. 9.264. Parasa vivida (African Stinging Caterpillar); Kenya.



Thosea sinensis (L.)

Common name. Slug Caterpillar
Family. Limacodidae (= Cochlidiidae)
Hosts (main). Tea and members of the Theaceae.
(alternative). Coffee, Cocoa, Sugarcane, Coconut, etc.
Damage. As with all Limacodidae this caterpillar eats leaves and occasionally will defoliate a bush or tree, but is also a pest because it bears urticating setae on the body which are irritating to the field workers, particularly tea pickers.
Pest status. Usually only a minor pest, but *Thosea* occurs in S.E. Asia as at least six to eight species, some of which are of some importance as pests on tea and others on oil palm.
Life history. Details are not known for this species but they are presumably similar to those of other members of this family.

The caterpillar is short, broad and rather flattened and bears the scoli along the lateral margins only; when mature, it is about 20–24 mm in length, green in colour but with a bright yellow dorsal stripe. Pupation takes place in a subspherical, hard brown cocoon stuck on to the bark of the plant or on to a leaf surface (as illustrated). The adult of this species is a plain dark brown in colour, and with a wingspan of 3–4 cm.
Distribution. This species is recorded from India, mainland S.E. Asia, China, and parts of Indonesia. Within this area there are at least 6–8 other species of *Thosea* recorded from tea and oil palm, and other hosts, such as soaghum, millet and many heguminosae.
Control. It was pointed out by Wood (1968) that on oil palm in Malaysia the outbreaks of stinging/slug caterpillars always occurred in areas with a long history of contact insecticide use. The assumption is that the pesticides upset the natural population balance by killing predators and parasites rather than the pests, which at that time only occurred in very small numbers and were not the primary targets for the contact insecticides at all.

Effective insecticides are endrin, parathion and BHC, as foliar sprays, with fenitrothion and fenthion as alternatives.

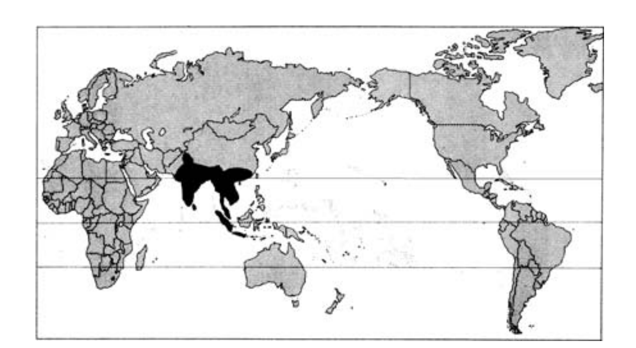


Fig. 9.265. Thosea sinensis (Slug Caterpillar); S. China.







Antigastra catalaunalis (Dup.)

Common name. Sesame Webworm
Family. Pyralidae
Hosts (main). Sesame (*Sesamum indicum*)
(alternative). No wild hosts recorded, but two ornamentals (*Antirrhinum* and *Durante*).
Damage. Young leaves and shoots are webbed together and eaten, and pods are bored by small caterpillars.
Pest status. A minor pest of sesame throughout Kenya and N. Uganda, and other areas in the tropics, with occasional serious outbreaks.
Life history. Eggs are oblong, 0.36 × 0.25 mm and laid singly on young leaves or on flowers, change from greenish-white, through yellow, grey, and finally to red before hatching. Incubation takes 2–6 days.

The larva is a white caterpillar when first hatched, but later turns green with small black spots. There are five larval instars lasting for 15–18 days according to temperature. The mature caterpillar is about 14 mm long. The caterpillars roll up and web together the young leaves with silk at the top of the shoot, and feed inside the rolled-up mass. Flowers are also eaten, and the caterpillars may bore within the pods.

Pupation takes place in a silken cocoon on a leaf or in the surface litter on the ground. The pupa is slender, greenish-brown, and 9–10 mm long. The pupal period varies from 4–9 days.

The adult is an orange-brown, night-flying moth with a wingspan of about 16 mm. After a pre-oviposition period of 2–5 days the moth may live a further 5–6 days and lay about 20 eggs.

Distribution. Old World tropics and subtropics, including S. Europe, USSR, Africa, India, Bangladesh Sri Lanka, and Burma. (CIE Map No. A. 452).

Control. Planting all the sesame crops in one area in the same rainy season so that a close season occurs between successive crops is recommended.

When insecticides are required effective treatment is a foliar spray of carbaryl or endosulfan.

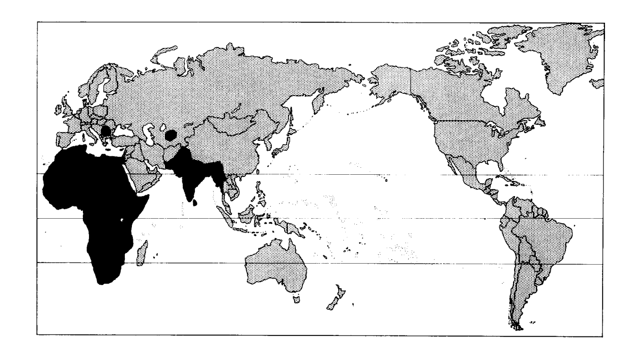
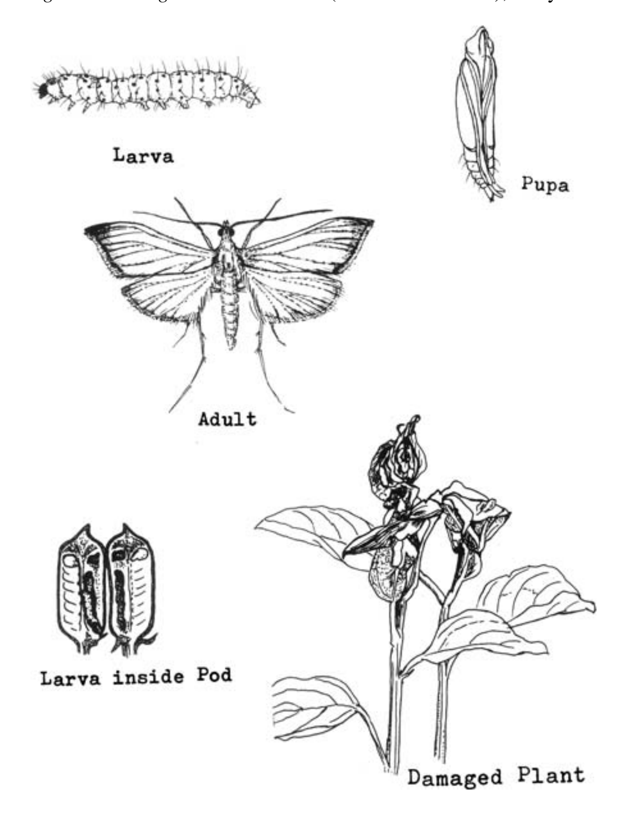


Fig. 9.266. Antigastra catalaunalis (Sesame Webworm); Kenya.



Chilo orichalcociliella (Strand)

Common name. Coastal Stalk Borer
Family. Pyralidae
Hosts (main). Maize, sorghum, finger millet and sugarcane.
(alternative). Wild grasses, especially guinea grasses (*Panicum* spp.) and wild sorghums (*S. verticilliflora* and *S. versicolor*).
Damage. The damage is much the same as for *C. partellus*, with 'dead-hearts' in small plants, windows in the upper leaves, and caterpillars boring in the stem of older plants.
Pest status. This was the most important stalk borer in the coastal provinces of Kenya and Tanzania, but since 1961 *C. partellus* has become the dominant species.
Life history. Egg-laying starts about nine days after maize germination. The adults originate partly from standing late-planted maize and partly from wild grasses. The egg stage usually lasts about 4–6 days.

The caterpillars are almost indistinguishable from those of *C. partellus* and take some 27 days to mature. The first generation of larvae are usually not numerous and seldom do serious damage.

Pupation takes place in the stems of the host plant, and the time required for development is about six days.

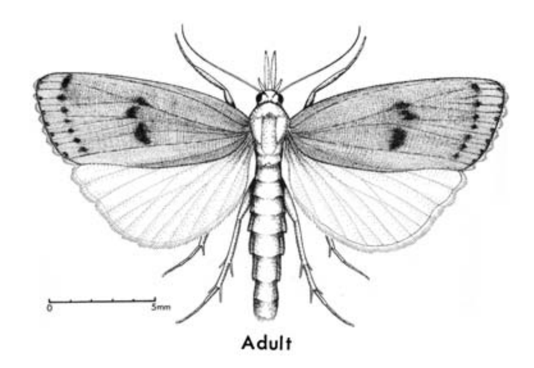
The adult moths are 10–14 mm long with a wingspan of about 28 mm. The forewing is pale brown with three dark spots in the centre and a subterminal row of about seven small dark spots; the hindwing is pale brown.

The first generation moths lay their eggs on the same maize plants, and the second generation of larvae tends to be much larger and more damaging. Both generations take about 36 days to develop. When the second generation adult moths emerge the maize plants are generally too old to be attractive for egg-laying; these adults usually lay their eggs on wild grasses or late-planted maize.
Distribution. E. Africa, Nigeria, Malawi, and Madagascar. More than 40 species of *Chilo* are known feeding on Gramineae in Africa and Asia.
Control. Destruction of all old maize plants and tall grasses by burning in the dry season before planting is advocated. Simultaneous planting of large areas of maize at the start of the rains, and the application of fertilizers to impoverished or poor soils are additional cultural methods of reducing borer populations and damage.

Only early-planted maize on fertile soil is worth spraying with insecticides; the usual insecticides employed are DDT, γ-BHC, carbaryl, etc., either as dust or spray in low volume.

See also p. 459, 'Control of cereal stalk borers'.

Fig. 9.267. Chilo orichalcociliella (Coastal Stalk Borer); Kenya.



Chilo partellus (Swinhoe)
(= *C. zonellus* (Swinhoe))

Common name. Spotted Stalk Borer (Pink Borer)
Family. Pyralidae
Hosts (main). Maize and sorghum, bulrush millet, sugarcane rice, finger millet, wheat.
(alternative). Various species of wild grasses.
Damage. In young plants this pest causes a typical 'dead-heart'; in older plants the upper part of the stem usually dies due to the boring of the caterpillars in the stem pith. All parts except roots may be boted.
Pest status. Since 1961 this has been the dominant pest in the coastal provinces of E. Africa. A major pest of maize and sorghum in India and E. Africa, not unimportant on other cereals, but actual crop losses following attack are not easy to demonstrate.
Life history. The eggs are flattened, ovoid, and scale-like, about 0.8 mm long. They are usually laid on the underside of a leaf-near the midrib, in 3–5 imbricated rows in groups of 20–100 Each female lays about 300 eggs. Hatching takes 4–10 days.

The young larvae migrate to the top of the plant where they mine the sheaths and tunnels in the midrib for several days, producing characteristic leaf windowing. They then either bore down inside the funnel, or else move down the outside of the stem and bore into it just above an internode. In older plants the larvae may live in the developing heads. Larval development takes 28–35 days; the mature caterpillar is 20 mm long, buff-coloured with four pale longitudinal stripes, and a brown head capsule and thoracic shield.

Pupation takes place in the stem in a small chamber, and takes 7–10 days. Pupa with cremaster multi (8–9).

The adult moths are not large, being 18–30 mm across the wings; the male is smaller and darker than the female. The male has forewings pale brown, with dark brown scales forming a streak along the costa; the hindwings are a pale straw colour. The female has much paler forewings and hindwings almost white. The adults are short-lived. (2–5 days usually).

The life-cycle takes about 29–48 days, and there are at least 5–6 generations per year.
Distribution. E. Africa and Southern Africa, India, Sri Lanka, Nepal, Bangladesh, Vietnam, Sikkim, and Indonesia Thailand (CIE map no. A184).

Essentially a pest of hot lowland areas, and is seldom found above an altitude of 1500 m.
Control. Crop residues should be destroyed as should volunteer plants. Chemical control of *Chilo* is not generally very successful; there is a breeding programme in E. Africa breeding sorghum for resistance to *Chilo*.

The insecticides generally used are carbaryl and endosulfan as dusts or sprays, but several applications are necessary (see *C. polychrysus*).

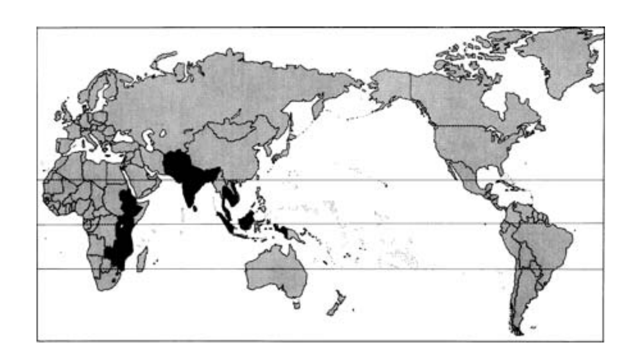
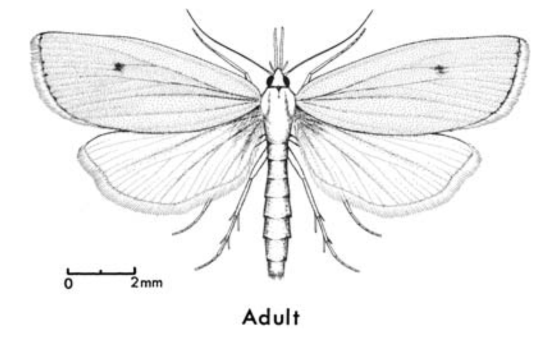


Fig. 9.268. Chilo partellus (Spotted Stalk Borer) Adult; Kenya.



Chilo polychrysus (Meyr.)

Common name. Dark-headed Rice Borer
Family. Pyralidae
Hosts (main). Rice
(alternative). Maize, sugarcane, and grasses.
Damage. The caterpillars bore the stem. Infested plants are liable to break at the node. Young plants show a characteristic 'dead-heart'.
Pest status. This is the most important rice stem borer in Malaysia, often killing the plants. The fourth instar caterpillar is the most destructive stage.
Life history. The eggs, which are scale-like in appearance, are laid in batches of 30–200 in rows along the undersurface of the leaves. Hatching takes 4–7 days.

The newly hatched caterpillars feed actively on the inner tissue of the leaf sheath. After a few days the caterpillars bore into the stems and feed on the stem tissue. They particularly feed at the nodes of the stem, so weakening the stems that they easily break at this point. Mature caterpillars have moulted five times, have a black head capsule and thoracic plate, and are 18–24 mm long and about 2.4 mm broad. Larval development takes about 30 (16–43) days.

Adults emerge in six days, and live for 2–5 days. The moths are 10–13 mm long with a wingspan of 17–23 mm. The forewing is uniform pale yellow with a cluster of small dark spots in the centre, and the hindwing white.

The total life-cycle takes 26–61 days; there are probably six generations per year.
Distribution. India, Pakistan, Bangladesh, Burma, Malaysia, Indonesia, Thailand, Vietnam, Laos, Sabah, and the Philippines.
Control. Clean cultivation is probably sufficient for control purposes in many areas, but in areas of intensive cultivation losses can be high. Where rice is grown under fairly natural conditions levels of parasitism are usually high and it is often preferable to avoid the use of pesticides, for they may destroy more parasites than the pests themselves.

Foliar sprays of parathion, and parathion-methyl are successful, but their mammalian toxicity is too high for safe use on a large scale. Endrin, dieldrin, trichlorphon, dichlorvos and diazinon carbaryl, endosulfan have also been successful, but several applications at weekly intervals are required.

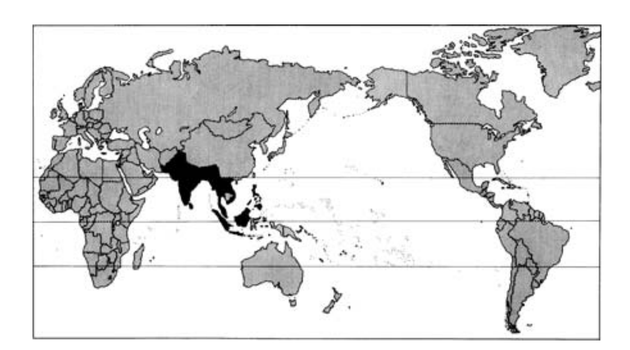
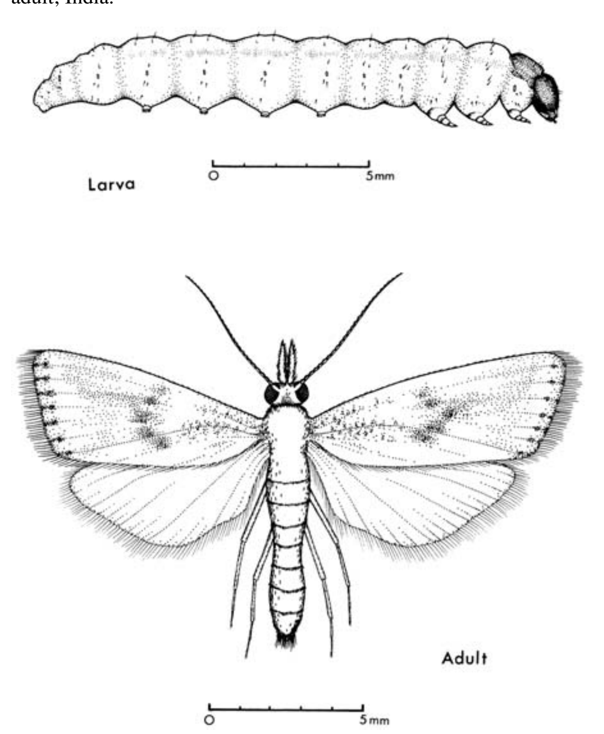


Fig. 9.269. Chilo polychrysus (Dark-headed Rice Borer) larva and adult; India.



Chilo sacchariphagus Bojer

(= *Proceras venosatus* (Wlk.))

Common name. Sugarcane Stalk Borer
Family. Pyralidae
Hosts (main). Sugarcane
(alternative). Wild cane and other species of Gramineae.
Damage. The larvae bore in the stem, making a cavity that invariably becomes infested with bacteria, fungi and rots. Because of the solid state of this stem each larva usually only burrows within a single internode and leaves a large emergence hole. Before penetrating the stem the first instar larvae feed on the leaf-sheath making small 'windows' in the leaves that enlarge as the leaves expand.

Pest status. A serious pest of sugarcane in S.E. Asia, Madagascar and Mauritius, but is replaced by other species on mainland Africa. In S.E. Asia references to damage by *'Diatraea saccharalis'* usually refer to this species. (*D. saccharalis* only occurs in the New World.)
Life history. Details are not known, but it is expected to be similar to that of *Diatraea saccharalis* and the other species of *Chilo*.
Distribution. Madagascar, Mauritius, Java, Sumatra, Malaya, Indo-China, S. China and Taiwan.
Control. The most effective method of controlling sugarcane borers is through the use of biological control and resistant varieties of plant. In Taiwan liberation of *Trichogramma australicum* resulted in stalk borer infestation decreases of 37–54%, and several varieties of cane have been shown to have definite adverse effects on borer development.

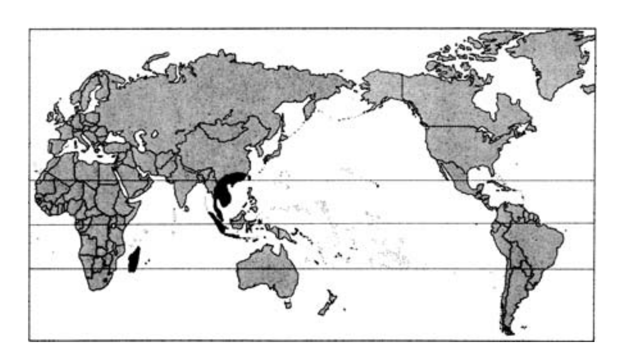
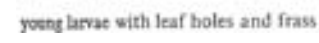
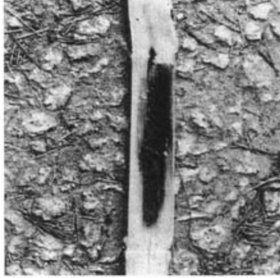


Fig. 9.270. Damage to sugarcane by *Chilo sacchariphagus* (Sugarcane Stalk Borer); S. China.



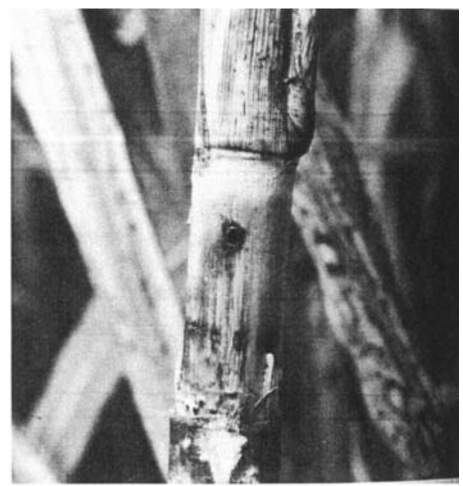


young larvae with leaf holes and frass



larval damage inside stem





emergence hole of adult moth

Chilo suppressalis (Wlk.)
(= *C. simplex auctt.*)
(= *C. oryzae Fletcher*)

Common name. Asiatic Rice Stalk Borer
Family. Pyralidae
Hosts (main). Rice, maize.
(alternative). Millets, Sorghum, sugarcane, various wild species of *Oryza*, and many wild grasses.
Damage. Larval damage consists of boring in the stem resulting in 'dead-hearts' in the young plants, and damaged stems in older plants. One caterpillar may destroy up to ten plants.
Pest status. A very serious pest of rice in China and Japan especially, where crop damage of 100% has been recorded. In Japan, despite heavy pesticide applications, the rate of paddy infestation has still averaged 4–5% with an average loss of 175 kg/ha.
Life history. The eggs are similar to those of *C. polychrysus*, and hatch in 4–10 days. (300 eggs/♀).

The caterpillars have a yellowish-brown head, and have three faint dorsal, and two pale lateral stripes, brown in colour. After 33 days the caterpillar is fully grown and is 20–26 mm long and 2.5 mm broad.

The reddish-brown pupa is 11–13 mm long and 2.5 mm broad; the pupal period is six days. Pupa has cremastes with only 6 points.

The moth is very similar to *C. polychrysus* in colour but without wing spots, and is slightly larger in size; it is 13 mm long with a wingspan of 23–30 mm, although females may reach 35 mm. The adults live for 3–5 days.

The life-cycle takes 40–70 days. or more (1–5 generation/year).
Distribution. Found in Portugal France Spain, India, Pakistan, Bangladesh, S.E. Asia, China, Korea, Japan, Philippines, Indonesia, Papua New Guinea, West Irian Hawaii and N. Australia (CIE map no. A254).
Control. Control is as for *C. polychrysus*.

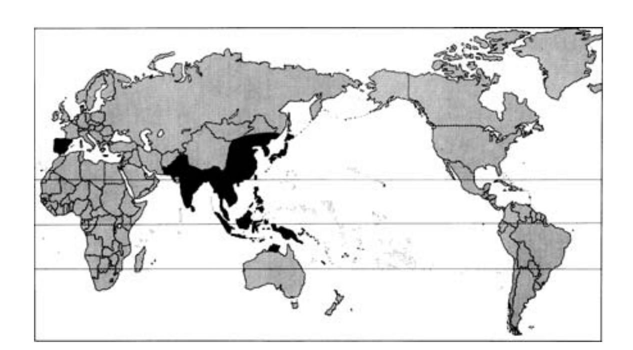
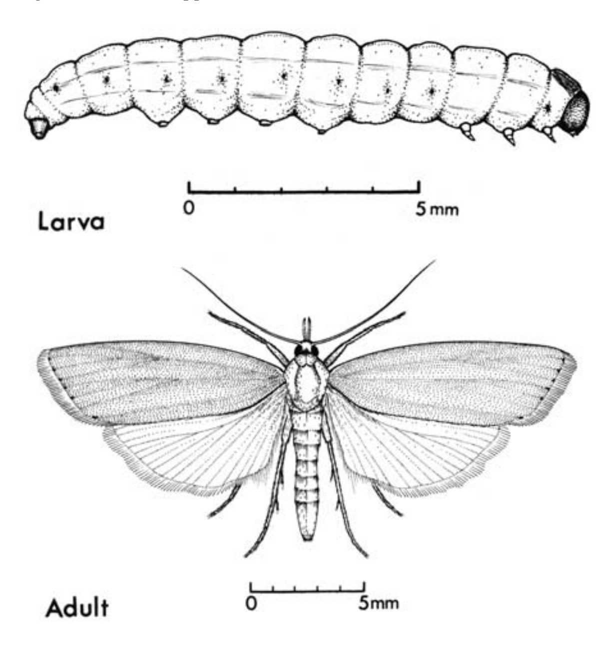


Fig. 9.271. Chilo suppressalis (Asiatic Rice Stalk Borer); India.



Cnaphalocrocis medinalis Gn.

Common name. Rice Leaf Folder (Rice Leaf Roller)
Family. Pyralidae
Hosts (main)**.** Rice
(alternative). Grasses of various species.
Damage. The caterpillars infest the leaves of young plants; they fasten the edges of a leaf together and live inside the rolled leaf. The green tissues, particularly the chlorophyll, are eaten by the caterpillars and the leaf dries up. In heavy infestations the plants appear scorched, sickly and twig-like.
Pest status. Occasionally a rice pest of some importance. Plants are susceptible to attack up to ten weeks after transplanting.
Life history. The eggs are laid singly or in pairs on the young leaves; they are flat and oval, and yellow in colour. Hatching takes place after 4–7 days.

The caterpillars live inside the folded leaves for 15–25 days, and are slender and pale green.

Pupation takes place inside the rolled leaf; the pupa is dark brown, and the adult moth emerges after 6–8 days.

The adult moths often fly by day; they are small (8–10 mm long; wingspan of 12–20 mm), orange-brown with several dark, wavy lines on the wings; the outer margin of the wings is characterized by a dark terminal band.

The life-cycle generally takes 25–35 days; in some areas there are four generations per year.
Distribution. Madagascar, Pakistan, India, Bangladesh, Sri Lanka, S.E. Asia, China, Korea, Japan, Philippines, Indonesia, West Irian, Solomon Isles, and E. Australia (CIE map no. A212).
Control. Removal of grass weeds from bunds around the paddy fields helps to reduce the pest population.

Light-trapping of adults has been successful in some instances.

In severe outbreaks sprays of DDT, BHC, or dieldrin effectively controlled the pest. Endosulfan, fenthion, fenitrothion, and phosphamidon have also been successful as sprays, as has diflubenzuron.

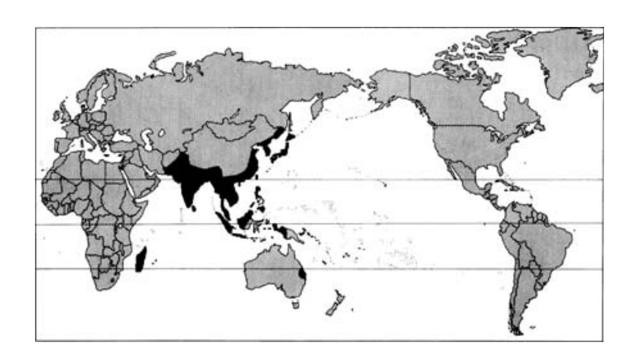
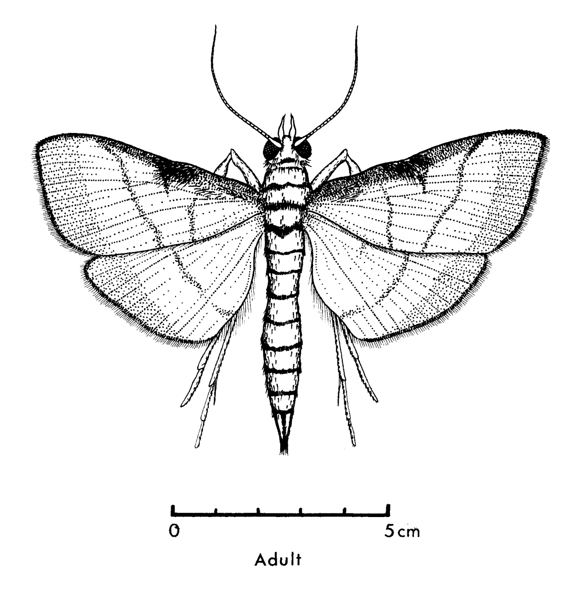


Fig. 9.272. Cnaphalocrocis medinalis (Rice Leaf Folder); India.



Diatraea saccharalis (F.)

Common name. Sugarcane Borer
Family. Pyralidae
Hosts (main). Sugarcane
(alternative). Maize, sorghum, rice, and many grasses.

Damage. The larvae bore in the internodes of the cane, and the larval excavation usually becomes infected with bacteria and/or fungi leading to rots. Usually one larvae only bores in one internode, because of the density of sugarcane stems. The emergence hole, through which the adult leaves the stem, is usually conspicuous.

Pest status. The major pest of sugarcane in the New World, although there are 4–5 other species of *Diatraea* important on cane in this region. Crop losses have been difficult to assess accurately because of compensatory growth, but it is thought that for every 1% of internodes bored sugar losses amount to 0.5–0.7%.

Life history. Eggs are usually laid within the leaf sheath (as with most stalk borers) and the young larvae feed on the epidermis of the leaves. After about a week the young larvae penetrate the stem and start to excavate the internode; larval development continues here until maturity. Mature larvae then bite an exit hole through the stem wall before they pupate, still within the stem. The larvae are creamywhite with prominent dark spots.

The number of larval instars varies from five to six to as many as eight, and the life-cycle takes from 35–50 days; in the tropics there may be seven generations annually, but at the northern and southern limits of its distribution four (and a partial fifth) generations are usual. In these regious larvae over-winter in a state of diapause in stubble and broken pieces of cane stalk.

The adults are small brown moths, with a wingspan of 18–29 mm; the forewings are yellow-brown with two faint oblique brown stripes, and a dark discal spot. The different species of *Diatraea* can only be reliably identified using the genitalia.

Distribution. Southern USA, W. Indies, C. and S. America (CIE map no. A5).

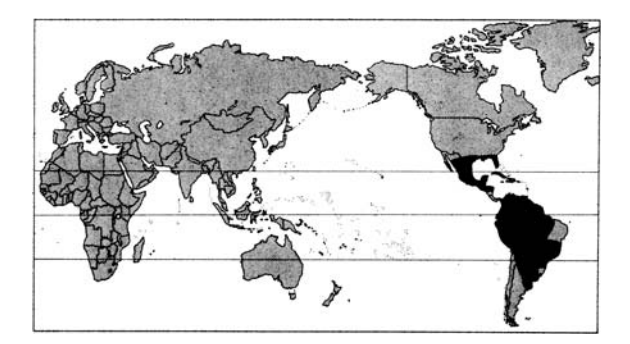
Control. The pest spectrum on sugarcane in most parts of the world is very large and complex, although in any one location probably not more than a dozen pests are of particular importance. In the past, pest problems often arose following prolonged use of contact insecticides, and now in most areas of intense sugarcane cultivation a careful and rational pest management programme is practised based upon the following.

Cultural practices: destruction of crop residues; careful double-cropping.

Resistant varieties: high levels of resistance are unlikely to be achieved, but a number of commercial varieties now show low levels of resistance, which helps to reduce borer damage.

Biological control: parasitic Hymenoptera are used to destroy the larvae and eggs; *Trichogramma* for the eggs, *Apanteles* and others for the larvae.

Chemical control: now generally restricted in use to the southern USA where borer generations are discrete, and only against the second and third generations if the populations are sufficiently large monocrotophos and carbofuran as foliar sprays, and endrin or azinphos-methyl granules.



Eldana saccharina Wlk.

Common name. Sugarcane Stalk Borer
Family. Pyralidae
Hosts (main)**.** Sugarcane, and in some areas maize and cassava.

(alternative). Other cereal crops and wild grasses, including rice and *Cyperus* sp. basically a pestol cyperaceae now adapted to Gramineae.

Damage. When very young plants are attacked 'dead-hearts' result, followed by tillering of the plant. Older plants or ratoon cane have internodes bored.

Pest status. A pest of some importance in Africa only; first recorded outbreak on sugarcane was in Tanzania in 1956, and in Uganda in 1967.

Life history. The eggs are oval, yellow, and laid in batches on the soil surface, although some may be laid on the leaf bases or in cracks on mature stalks. On average 200 (100–500) eggs are laid per female in batches of 10–15 (3–200 have been recorded). The female starts egg-laying the second night after emergence. The incubation period is 5–6 days at 25°C.

The larval period is 30–35 days in Uganda, and there are six larval instars. When burrowing in the stem the larvae characteristically push their faecal pellets outside. First instar larvae typically feed on the upper surface of the leaf sheath, and then later penetrate the bud and enter the stem. The larvae are mainly found in the lower parts of the stems, but in heavy infestations may be found in all parts of the stem.

Pupation takes place in the plant, in the stem or on the leaf sheath, and takes some 7–14 days (mean 10).

The adult male has a wingspan of 28–30 mm, and the female 39–40 mm. Emergence takes place at night, with mating on the following night. They have pale brown forewings, each with two small spots in the centre, and whitish hindwings with a short fringe. The adults live for 3–8 days.

Distribution. Africa only; Zaïre, Nigeria, Sierra Leone, Chad, Ghana, Mozambique, Zululand and E. Africa.

Control. Endrin as a foliar spray, applied four times at three-week intervals, gave some control of this pest in Tanzania.

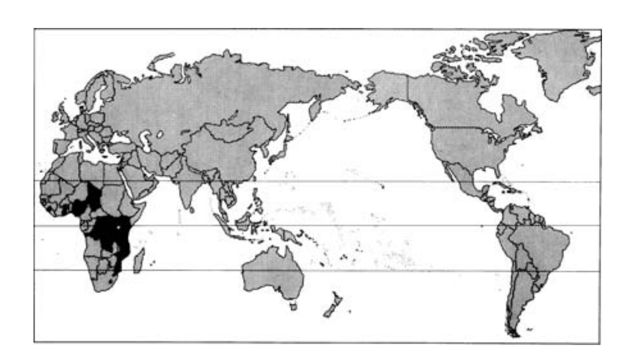
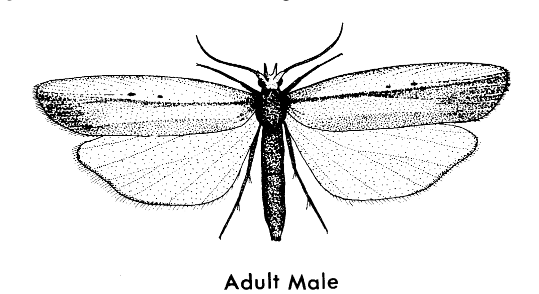
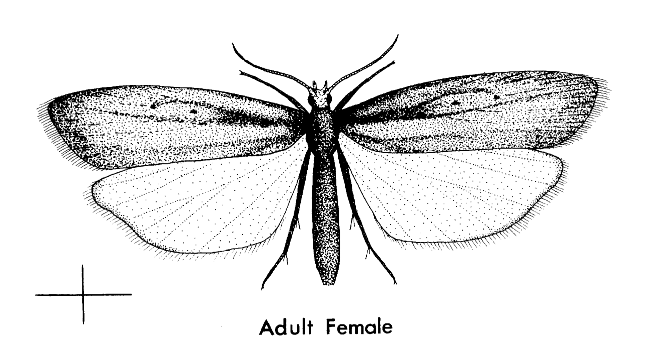


Fig. 9.273. Eldana saccharina (Sugarcane Stalk Borer) Adults.





Ephestia cautella (Walker)

Common name. Almond Moth (Tropical Warehouse Moth; Dried Currant Moth; Date Moth)
Family. Pyralidae
Hosts. In the wild this and the other stored products Pyralidae are found on ripening fruits (including fallen and dried fruits) of date palm, and close relatives, and other fruits (cocoa pods etc.); but they are most serious as pests of stored products, both dried fruits and grains.
Damage. The larvae eat the fruit and the grains and produce a large amount of silk webbing over the feeding surfaces.
Pest status. A serious pest of stored products throughout the warmer parts of the world, and in heated stores in temperate regions; a wide range of stored produce is attacked, and damage may be very heavy.
Life history. Eggs are laid in the produce, or on the fruit bunches; each egg is globular, white turning orange; each female lays up to 250 eggs.

The larvae of *Ephestia* species are all very similar and can only be separated by detailed chaetotaxy; they are whitish-grey with many dark setae and small brown spots along the body; the head capsule is dark brown; full-grown size is about 12–15 mm. First-instar larvae generally feed on the seed germ, moving about freely in the produce. They pupate in crevices or where two surfaces touch (adjacent bags, fruits, etc.), in a silken cocoon.

The adults are small greyish moths, with rather indistinct markings on the forewings; body length about 7–8 mm and wingspan 14–18 mm; at rest the wings are folded along the abdomen. Adults live for about two weeks and fly quite strongly.

The life-cycle at 28°C and 70% RH is 6–8 weeks; under warm conditions breeding may be continuous, and there may be many generations annually.
Distribution. A cosmopolitan pest species found throughout the warmer areas of the world and in heated stores in temperate regions.
Control. To kill the emerging moths before they can lay their eggs, sprays of pyrethroids are usually recommended in stores at serious risk, either as space sprays (to kill flying insects) or surface sprays. Dichlorvos slow-release strips are also successful for control of these moths.

General fumigation and the measures usually taken against stored products beetles are also usually effective against the stored products moths (see page 297).

Sex pheromones are now commercially available for the main species of *Ephestia* and can be used in stores both for monitoring moth populations and for trappingout male moth populations if the stores are small.

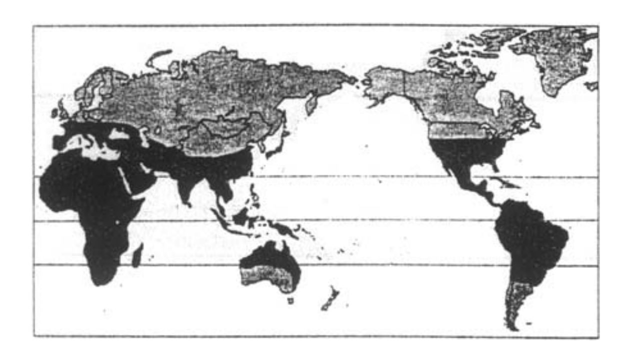
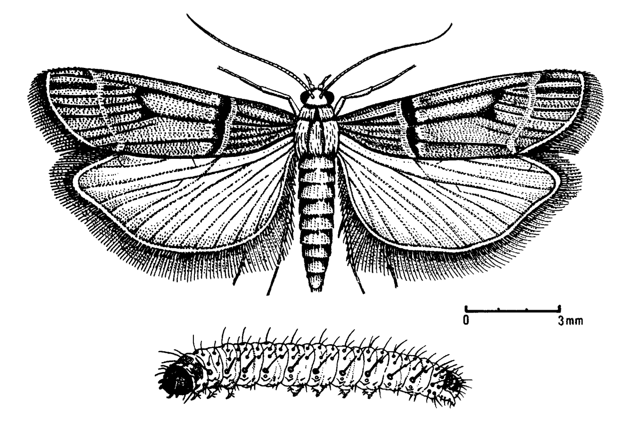


Fig. 9.274. Ephestia cautella (Tropical Warehouse Moth); India.



Ephestia elutella (Hübner)

Common name. Warehouse Moth (Cacao Moth; Stored Tobacco Moth)
Family. Pyralidae
Hosts (main)**.** Stored cocoa beans, dried fruits, nuts and oil seeds.
(alternative). Stored grains, pulses, processed flours and foodstuffs, and tobacco.
Damage. Direct damage consists of the larvae eating the produce; this is another primary pest that also selectively eats the germinal part of the seeds; but indirect damage by contamination may often be of more economic consequence.
Pest status. A serious pest of stored produce throughout the subtropical and less cold temperate regions of the world; not abundant in the actual tropical regions where it is replaced by *E. cautella*.
Life history. Eggs are laid in crevices in the produce of sacks, and hatch after 10–14 days. The caterpillars burrow rapidly into the produce, and as they feed they spin silken webbing which binds the food together. They feed for several weeks, then when full grown (at about 12–14 mm) they usually have a small mass migration to seek favourable pupation sites, often leaving the produce to roam over the warehouse structure. In suitable crevices they spin silken cocoons in which they rest. In the UK many larvae overwinter, but some pupate immediately; in warmer regions they all pupate immediately, for a period of 1–3 weeks.

The adults are small brownish moths, about 5–9 mm long, wingspan 15–19 mm; the forewings have distinctive banding. They live for about two weeks, and the females lay most of their eggs (up to 500 recorded) in the first four days; they fly quite strongly and may start new infestations in buildings up to a kilometre away.

For these stored products pests the rate of development and final body size depends in part upon ambient conditions, and also on the type (quality) of food being eaten. Thus larval development may take from 20–120 days and final body size may vary from 8–15 mm long. Under optimum conditions the life-cycle can be completed in about 30 days (25°C and 75% RH); in the UK there is only one generation per year, but in more suitable climates breeding may be continuous.
Distribution. A cosmopolitan pest species, now dispersed completely throughout the world, but not abundant in the hotter tropical countries; it is basically a warm-temperate species.

Other species often found in association with this and the preceding species:
Ephestia calidella Guen. – (Date Moth) cosmopolitan in warmer regions.
Ephestia figulilella Greg. – (Raisin Moth) cosmopolitan in warmer regions.
Control. For control measures see page 420.

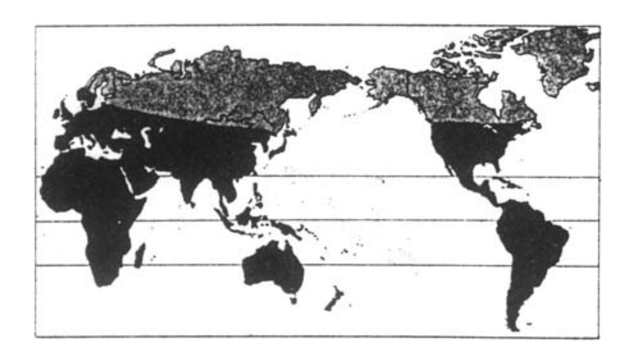
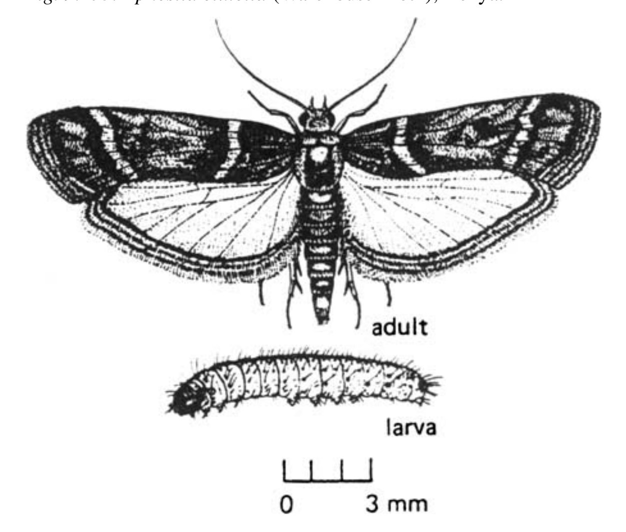


Fig. 9.275. Ephestia elutella (Warehouse Moth); Kenya.



Etiella zinckenella (Treit.)

Common name. Pea Pod Borer (Lima Bean Pod Borer)
Family. Pyralidae
Hosts (main). Beans and pea.
(alternative). Pigeon pea, cowpea, and other pulses.
Damage. The larvae feed inside pods, eating the developing seeds. The partly grown caterpillar may leave the original pod and enter one or more fresh pods before ceasing to feed.
Pest status. A widespread and common pest of various legume crops, sometimes causing serious damage and economic losses.
Life history. The eggs are oval, shiny white, 0.6 × 0.3 mm; laid singly or in small groups (2–6) on young pods. Hatching requires 3–16 days, according to temperature. Each female lays 50–200 eggs.

The caterpillar is blue-green with a yellow head, and reaches a size of 12–17 mm long. On hatching the larva takes about 1.5 hours to actually penetrate the pod. Cannibalism often occurs if several caterpillars enter the same pod. If the pod is opened the caterpillar wriggles very violently. The larvae typically leave their frass inside the pod. Total larval development takes 3–5 weeks.

Pupation takes place in the soil, in a silken cocoon, at a depth of about 3 cm; development takes 2–4 weeks.

The adult is a small brown moth, about 24–27 mm wingspan; the dark forewing bears a characteristic small median mark and has a white leading edge. The adult female may lay her eggs throughout her 2–4-week lifespan.
Distribution. A cosmopolitan species found throughout the world in warmer regions, but only one record from Australia (CIE map no. A.105).
Etiella behrii Zell. – (Lucerne Seed Web Moth) found in Australia feeding on soybean and alfalfa.
Control. A difficult pest to control in field infestations, for egg-laying occurs over a protracted period of time and repeated sprays of insecticides are required in order to achieve a reasonable level of control; this is usually not economic. If control was to be attempted, then weekly (or 10-day) sprays of the chemicals listed on page after flowering starts, could be used.

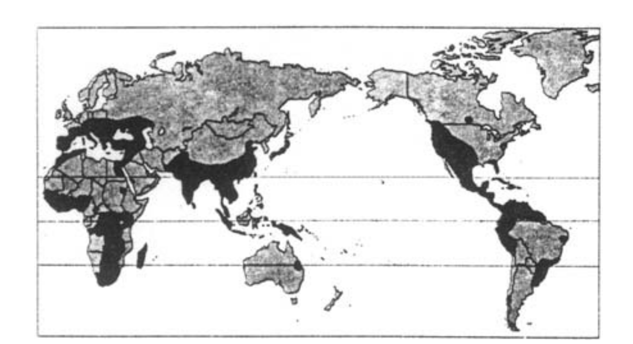
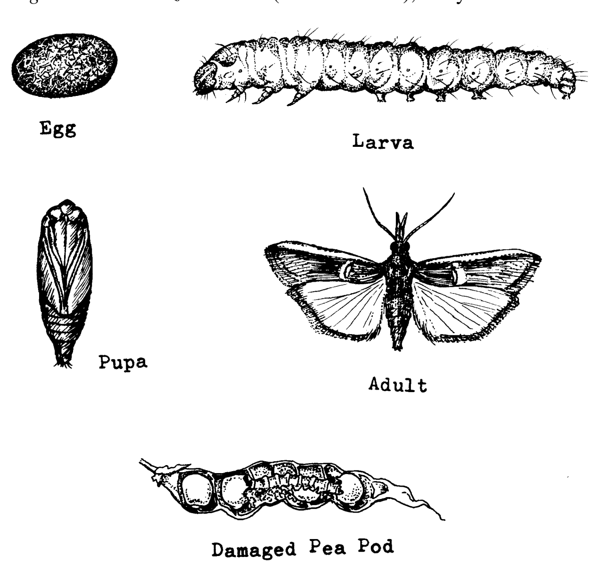


Fig. 9.276. Etiella zinckenella (Pea Pod Borer); Kenya.



Maliarpha separatella Rag.

(= *Rhinaphe vectiferella* Rag.)

Common name. White Rice Borer
Family. Pyralidae
Hosts (main)**.** Rice
(alternative). Wild rice and grasses.
Damage. Larval stem boring results in white heads and broken stems, although usually damage is not serious unless conditions are suitable for continuous cropping, as in parts of Madagascar. The larvae feed on the tissues inside the hollow stem of the rice plant, and can bore into the base of the stem and thence into other tillers.
Pest status. Only occasionally a serious pest in localities of continuous rice-cropping.
Life history. The eggs are laid close together in one cluster of up to 50 in number. They are stuck to the leaf by cement and as this dries it puckers the leaf so that the egg mass is enclosed inside a foliar envelope.

The larva is transparent-white with a dark brown head; as it ages it gradually turns yellowish and gets fatter. Larvae can be dispersed by wind, suspended on a silken thread. Mature caterpillars are about 18 mm long, and can go into a resting stage during a dry season. In Sierra Leone the larvae may lie dormant in the rice stubble for up to 20 weeks.

Pupation takes place in a loose cocoon in the rice stem. The pupa is brown with a red spot on the dorsal part of the fifth segment.

The adult male is about 15 mm long, and the female about 18 mm; wingspan is from 23–29 mm. The long, pale yellow wings overlap along the body at rest. On the paler forewings there is a marked reddish-brown line behind the costal veins. The hindwings are white with a metallic sheen.

There are usually three or four generations per year.
Distribution. Africa (W. and E. and S., Zambia, Malawi, and Madagascar), India, Sri Lanka, Burma, China, Papua New Guinea and West Irian (CIE map no. A271).
Control. Control measures are similar to those recommended for *Chilo polychrysus*.

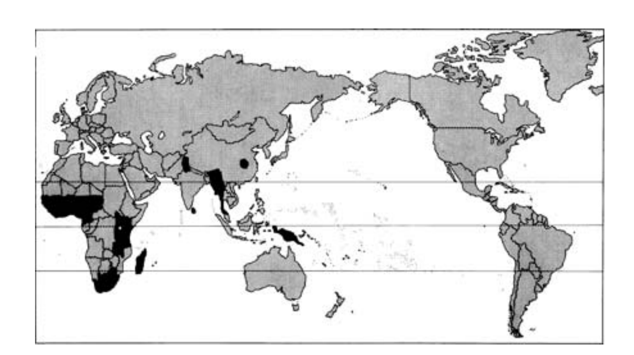
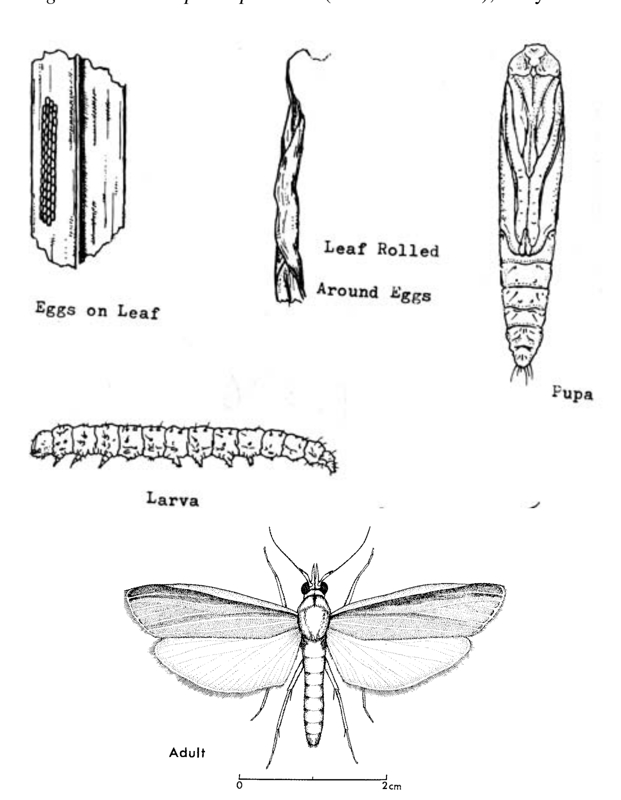


Fig. 9.277. Maliarpha separatella (White Rice Borer); Kenya.



Marasmia trapezalis (Gn.)
(? *Cnaphalocrocis*)

Common name. Maize Webworm
Family. Pyralidae
Hosts (main). Maize
(alternative). Millets, sorghum, sugarcane, rice, wheat and many wild grasses.
Damage. The larvae bind the two edges of the leaf together with silk to form a funnel and they feed inside by biting small pieces from the upper surface.
Pest status. Not usually a serious pest but infestations are quite common in some seasons, and they are quite conspicuous.
Life history. The eggs are laid along young leaves by the ovipositing female.

The larva is a pale greenish-yellow caterpillar, with conspicuous setae, and both head and thoracic shield reddish-brown. The fully grown caterpillar reaches a length of about 20 mm.

Pupation takes place in the rolled-up leaf to which the larvae fasten themselves with silken threads.

The adult is a small moth with 18–20 mm wingspan; the wings are greyish with shiny highlights (iridescence), and have three dark transverse stripes and a dark wide sub-terminal band; the hindwings have the stripes continuing and they converge on the anal point.
Distribution. Africe (Cameroons, Zaïre, Senegal, E. Africa, Madagascar); S.E. Asia, Australasia, Pacific islands, C. America, and Peru.
Control. Control measures are not usually required, but the usual caterpillar-killing insecticides, e.g. DDT, carbaryl, fenitrothion, tetrachlorvinphos, etc., should prove effective if at any time required.

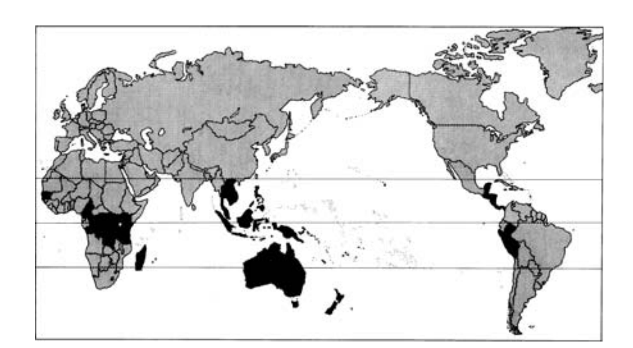
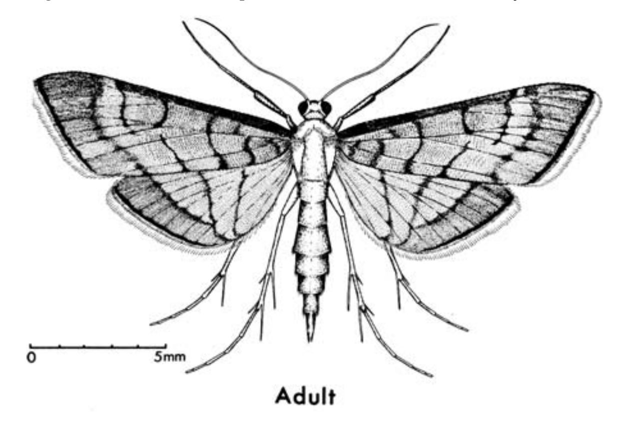


Fig. 9.278. Marasmia trapezalis (Maize Webworm); Kenya.



Maruca testulalis (Geyer)

Common name. Mung Moth (Bean Pod Moth)
Family. Pyralidae
Hosts (main). Beans and peas (Leguminosae), of all species but mostly *Phaseolus* spp.
(alternative). Groundnut, castor, tobacco, rice, and *Hibiscus* spp.
Damage. Leaves, flowers, flower buds and pods are eaten by the caterpillars, but the more serious damage is done in the pods where the seeds are destroyed.
Pest status. A regular but usually minor pest of pulse crops in E. Africa and other parts of the tropics, although occasional serious outbreaks have been recorded.
Life history. The eggs are laid singly in the flowers or buds, or on the pods of the host plant.

The caterpillar is whitish with dark spots on each body segment, forming dorsal longitudinal rows. Larvae expell frass from the pod. The mature caterpillar is about 16 mm long.

Pupation takes place in a silken cocoon in the pod, or more rarely in the soil.

The adult moth has brown forewings with three white spots, and the hindwing is greyish-white with distal brown markings; the wingspan is from 16–27 mm.
Distribution. Widespread in tropical and subtropical regions of the world.
Control. Effective chemicals include DDT, diazinon, endosulfan, pirimiphos-methyl, tetra-chlorvinphos, trichlorphon, cypermethrin and permethrin, as foliar sprays.

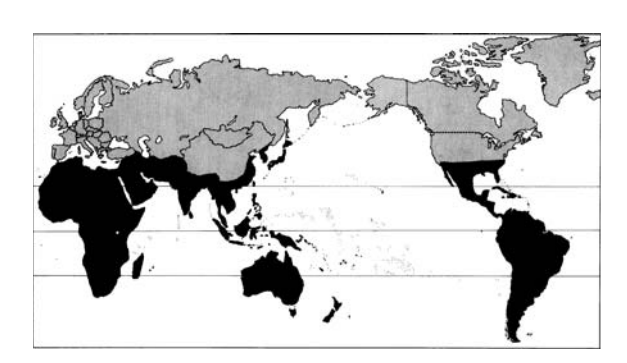


Fig. 9.279. Maruca testulalis (Mung Moth); Kenya.



Nacoleia octasema (Meyr.)

Common name. Banana Scab Moth
Family. Pyralidae
Hosts (main). Bananas
(alternative). *Pandanus*, manila hemp, maize, *Heliconia*, and nipa palm.
Damage. The caterpillars feed on the inflorescence of the banana as it develops, and cause a scab on the developing fruit. Further damage is caused by the frass accumulating in dark masses between the fingers and hands of the bunches. Attacks are not usually widespread, but individual bunches are severely damaged.
Pest status. A serious pest where it occurs, although not quite so serious in Papua New Guinea and some parts of Indonesia.
Life history. Eggs are laid in batches (typically about 15) on or near the flag leaf just before the bunch emerges. Each female moth can lay 80–120 eggs. The pale, greenish-white eggs hatch in about 4–6 days, and the small, transparent, yellow caterpillars crawl under the bracts of the banana inflorescence where they feed. As the larvae feed and grow they gradually turn pink. Up to 70 caterpillars may be found in a single inflorescence. The five instars take 12–21 days for completion.

Pupation takes place in a silken cocoon, constructed among the fruits, under the sheath or possibly sometimes on the ground; it takes 10–12 days.

The adult moths emerge in the evening, and only live for a few days. They vary somewhat in colour and size, wingspan being 16–26 mm (average 22 mm); colour from pale to dark brown with a series of dark spots and lines on both wings.
Distribution. Indonesia, Papua New Guinea, West Irian, Solomon Isles, New Caledonia, Fiji, Tonga, Samoa, and Australia (Queensland) (CIE map no. A383).
Control. Various attempts at biological control of the caterpillars by parasites (Tachinidae and Braconidae) are in progress at the present time.

The newly hatched caterpillars can be sprayed with DDT or a DDT + BHC mixture but these treatments are not very effective unless critically timed.

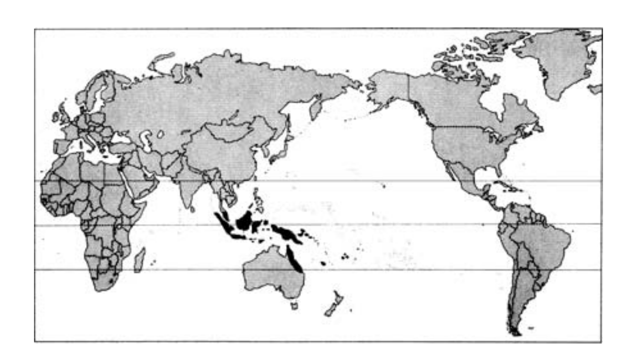
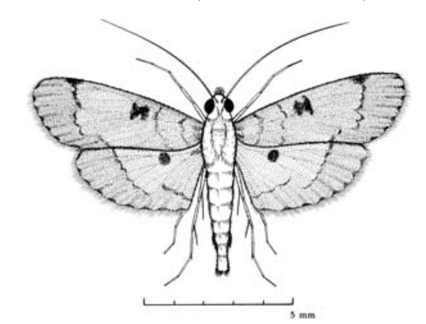


Fig. 9.280. Nacoleia octasema (Banana Scab Moth).



Parapoynx stagnalis Gn.
(*Nymphula depunctalis Gn.*)

Common name. Rice Caseworm
Family. Pyralidae (Nymphulinae)
Hosts (main). Rice
(alternative). Various aquatic grass species.
Damage. The caterpillar cuts tips of leaves to make the case in which it lives; the case is changed as the caterpillar grows. In heavily infested crops the loss of photosynthetic tissue can be critical and seedlings may die. Older plants generally are more tolerant of damage, and mature plants are seldom attacked. The larvae feed on the lower side of leaves lying flat on the water, or on submerged leaves.
Pest status. A serious pest of rice seedlings in many countries, but damage to older plants is slight.
Life history. The eggs are laid singly on the leaves; they hatch in 2–6 days, and after a few days the first instar larvae construct the first cases. One female moth usually lays about 50 eggs.

The caterpillar is pale translucent green, with a pale orange head. It is semi-aquatic in habits and can withstand prolonged immersion; it has slender gills along its sides and the case is always filled with water. The larval stage (with four instars) lasts for 15–30 days. The fully grown caterpillar is 13–20 mm long.

Pupation takes place inside the last larval case which is fastened to the base of the stem; it may take place under water but more usually above water level.

The adults emerge after 4–7 days, and can live for up to three weeks. The adults are small, delicate, snowy-white moths with pale brown spots on the wings; they have a wing-span of 15–25 mm.
Distribution. Nigeria, Ghana, Gambia, Cameroons, Zaïre, Malawi, Mozambique, Madagascar, Mauritius, Pakistan, India, Sri Lanka, Bangladesh, Burma, Malaysia, Thailand, Vietnam, Indonesia, Philippines, S. China, West Irian, Australia, and S. America (CIE map no. A176). Two other species are important pests of rice in Europe and Japan.
Control. Draining the water from infested fields for 2–3 days successfully kills the caterpillars, but they can also be killed by the addition of a kerosene film to the water.

The more successful insecticides used were parathion, malathion, BHC, dieldrin (Feakin, 1976).

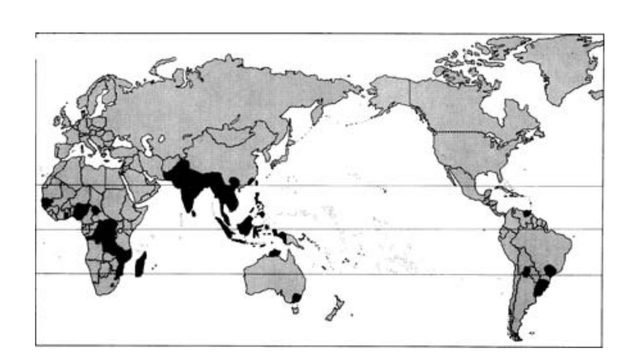
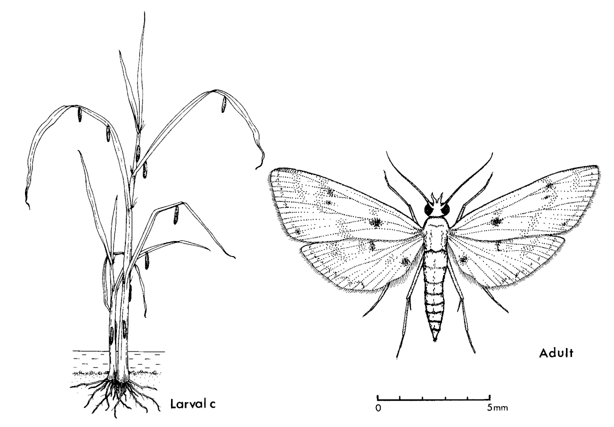


Fig. 9.281. Parapoynx stagnalis (Rice Caseworm); India.



Ostrinia furnacalis (Gn.)

(= *Pyrausta salientialis* (Snell.))

Common name. Asian Corn Borer
Family. Pyralidae
Hosts (main). Maize
(alternative). Sorghum, millets, Indian hemp, hops, *Artemisia*, and many other plants.
Damage. Attacked plants may have broken stems, with tunnels up the stem, and inside the cobs. There is windowing of leaves.
Pest status. An important pest of maize in Asia and Australasia; with heavy infestations losses can be very serious.
Life history. Eggs are laid in clusters of 10–40 underneath the leaves, each female laying from 500–1500 eggs, usually about one week before the formation of the female inflorescence. Incubation takes 3–10 days.

The young larvae initially scarify the underside of the leaves, then they feed on the spike and spin the inflorescences together. Later they tunnel into ribs of the leaves, and bore into the stem. After about three or four weeks the larvae are mature.

Pupation takes place in a cocoon in the soil or in the stem.

The adult is a yellowish moth, 12–14 mm long and up to 30 mm wingspan, with dark brown terminal bands and various wavy lines. The moths are active nocturnal fliers, and may fly for up to several miles. They live for 10–24 days.

There are one or more generations per year, according to temperature.
Distribution. Asia, and Australasia (CIE map no. A294).
Control. Cultural practices include destroying the stubble after harvest; using resistant or tolerant varieties of maize; planting late to avoid early egg-laying.

The aim of chemical control is to destroy the first instar caterpillars before they bore into the stem, recommended insecticides are trichlorphon as sprays or granules, parathion-methyl, parathion, and carbofuran.

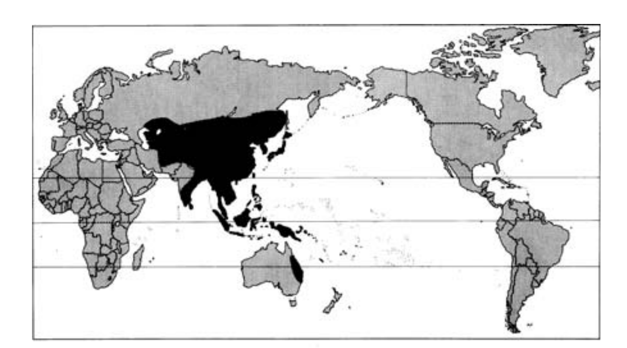
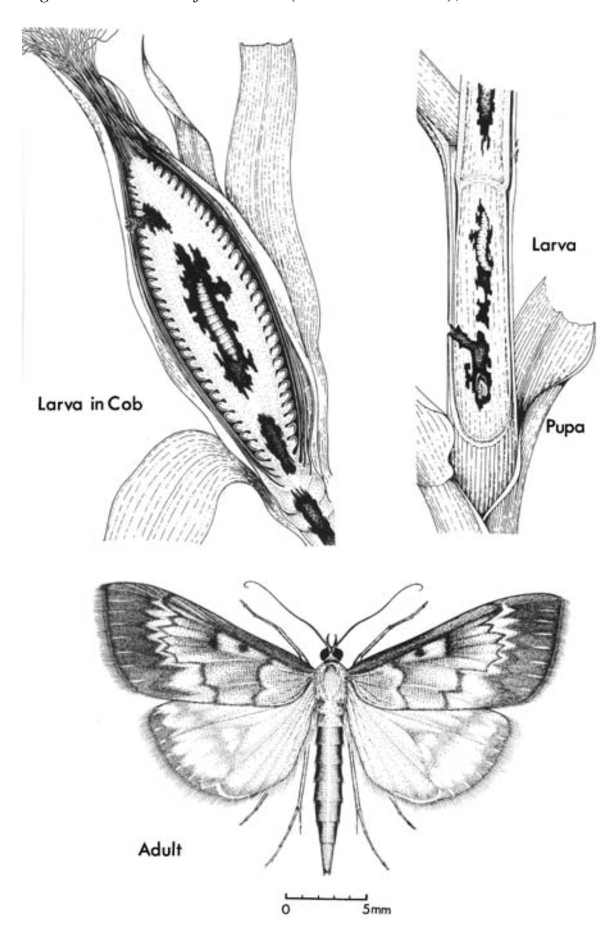


Fig. 9.282. Ostrinia furnacalis (Asian Corn Borer); S. China.



Plodia interpunctella (Hub.)

Common name. Indian Meal Moth
Family. Pyralidae
Hosts (main). Meals and flours, and farinaceous products in storage.

(alternative). Dried fruits (raisins, currants, sultanas), nuts, and some pulses and cereals.

Damage. The direct eating of the produce, especially the germinal part of grains, is the primary damage, but the secondary damage is the contamination of foodstuffs with larvae, frass and silk webbing.

Pest status. An important pest of stored foodstuffs throughout the tropics and subtropics; it is regularly imported into Europe and N. America where it will survive and develop so long as temperatures are fairly high (above 18°C) and the air not too dry (RH above 40%).

Life history. This species does not have the dark spots on the larvae that *Ephestia* have, and so is distinct from those species.

Each female lays some 200–400 eggs which are stuck to the substrate. The eggs hatch after about 4–6 days, and the larvae live and feed in the stored foodstuff, reaching a body length of 8–10 mm after about 12–20 days. At low temperatures and low humidities larval development takes considerably longer. The total life-cycle can be as short as 24–30 days under optimum conditions (30°C & 70% RH) but the duration depends upon ambient temperature and humidity.

The adult moth is distinctive, with the outer half of the forewings a coppery-red separated from the creamy inner half by dark grey bands; body length is 6–7 mm and wingspan is 15–20 mm.

In Europe there may be only one or two generations per year, but in the tropics up to eight may be expected.

Distribution. Worldwide in the tropics and subtropics, and in some parts of the temperate regions where temperatures exceed some 20°C.

Control. The regular practices of fumigation and spraying contact insecticides in food stores generally keep this pest under control.

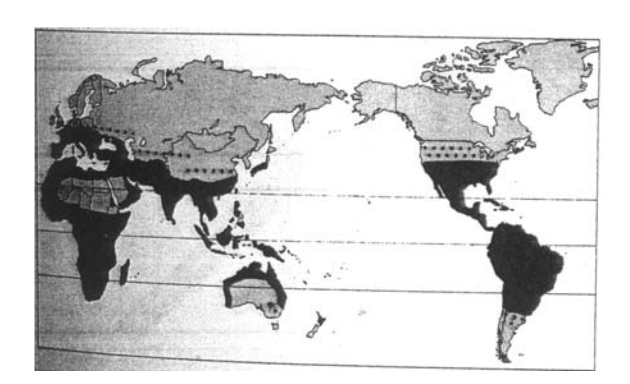
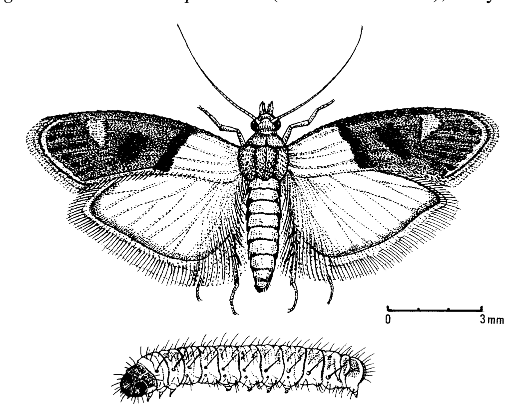


Fig. 9.283. Plodia interpunctella (Indian Meal Moth); Kenya.



Prophantis smaragdina (Butler)
(= *Thliptocera octoguttalis* (F. & R.))

Common name. Coffee Berry Moth
Family. Pyralidae
Hosts (main). Coffee (*arabica*)
(alternative). Various woody Rubiaceae.
Damage. Typical symptoms are berry clusters webbed together and one or more is brown, dry and hollow. Very young berries may be grazed.
Pest status. A minor pest of *arabica* coffee. Frequently of benefit since it eats out a little of the crop on overbearing branches. Occasional severe attacks have occurred when the entire crop on many trees has been destroyed.
Life history. The eggs are scale-like, laid singly on or near green berries; they hatch in about six days.

The larva is a reddish caterpillar about 14 mm long when fully grown. If it hatches out near a cluster of half-grown or larger berries, it bores into one of them, starting near the stalk. When one bean has been eaten, it leaves and wanders over the cluster joining the berries together with threads of silk before boring into a second berry. Feeding and web-spinning continue in this way until the caterpillar is fully grown. The larval period lasts for about 14 days.

The fully grown caterpillar passes through a resting stage of about four days, after which it usually drops to the ground and pupates between two leaves neatly stuck together. The pupal period is very erratic, lasting from 6–42 days.

The adult is a small, golden moth with wingspan of about 14 mm. There is a pre-oviposition period of 3–4 days. Adults live for two weeks.
Distribution. Africa from W. to E. and S.
Control. Trees should be examined at the times of flowering, and if buds or young berries are being eaten spraying with fenitrothion or fenthion should be done immediately, and repeated after 5–6 weeks.

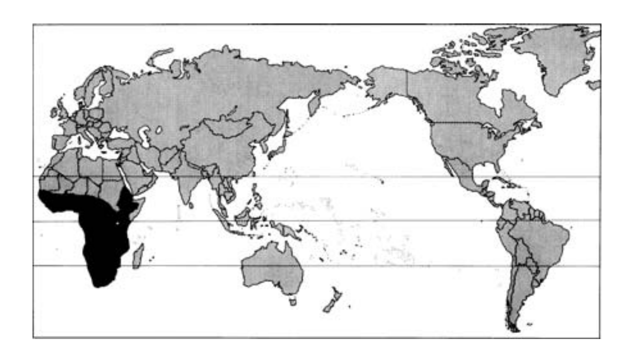
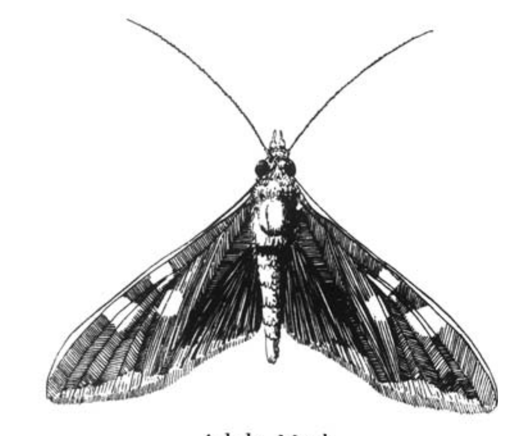
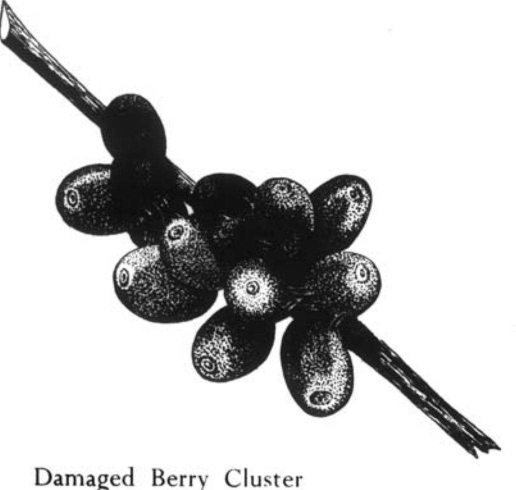


Fig. 9.284. Prophantis smaragdina (Coffee Berry Moth); Kenya.





Sylepta derogata (F.)

Common name. Cotton Leaf Roller
Family. Pyralidae
Hosts (main). Cotton
(alternative). Virtually confined to the Malvales, especially *Gossypium* and *Hibiscus*.
Damage. The leaves are curled and drooping, as the caterpillars eat the leaf margin. The defoliation of the plants results in premature boll ripening.
Pest status. A serious pest usually controlled by its parasites; only rarely is chemical control warranted. Probably the most common leaf-eating caterpillar on cotton.
Life history. The eggs are oval, smooth, rather flatened, and pale green, and they are laid singly or in groups on either side of the leaves.

The young larvae, after an initial period of wandering, congregate within a roll of leaf which they secure by spun silken threads. Up to ten caterpillars may be found in one roll. When partly grown the caterpillars disperse and each forms a separate roll. They are very agile, and are translucent green with a black head and thoracic shield; mature at about 20 mm.

Pupation takes place in the leaf roll or in debris on the ground; the pupa is brown, 10–14 mm long.

The adult is cream-coloured with brown wavy pencillings on both wings. Wingspan is 30–40 mm.

The life-cycle generally takes 4–5 weeks.
Distribution. Throughout the rain-fed cotton-growing areas of Africa, S.E. Asia, Australia and the Pacific islands (CIE map no. A397).
Control. Outbreaks of *S. derogata* are usually controlled naturally by its parasites. In some cases collection of the rolled leaves is recommended.

Should chemical control measures be required the following insecticides should be effective: DDT as a dust, and carbaryl as a spray, to be applied on the foliage at the first signs of damage or infestation.

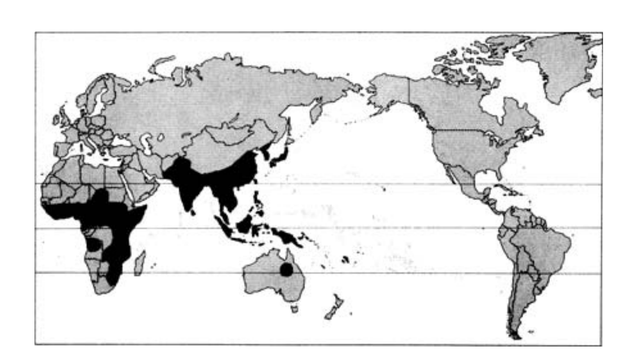
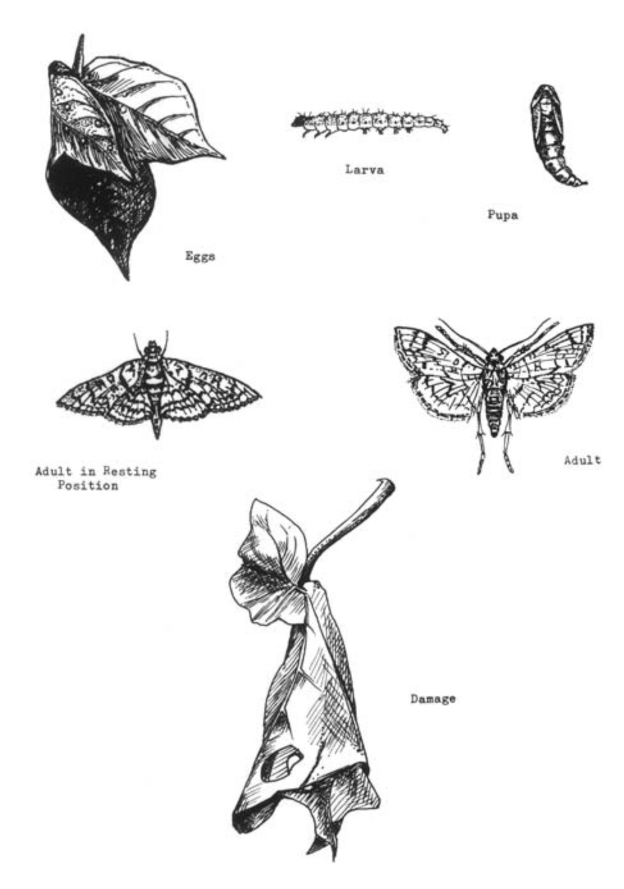


Fig. 9.285. Sylepta derogata (Cotton Leaf Roller); Kenya.



Scirpophaga incertulas Wlk.
(= *Tryporyza incertulas* (Wlk.))
(= *Schoenobius incertulas* (Wlk.))
(= *S. bipunctifera* (Wlk.))

Common name. Yellow Paddy Stem Borer
Family. Pyralidae
Hosts (main). Rice
(alternative). Wild rice and various wild grasses.
Damage. The caterpillars bore into the rice stems and hollow out the stem completely. Attacked young plants show 'dead-hearts' and older plants often break where the stem is hollowed out causing lodging.
Pest status. A serious pest of rice throughout India and S.E. Asia.
Life history. Egg masses are laid in batches of 80–150 on the leaf sheath, and covered with the brown anal hairs of the female moth. The incubation period is 4–9 days.

The caterpillars are yellow in colour, about 18–25 mm long when mature; the head capsule is black. Total larval development takes about 40 days. Pupation takes place inside the stem; the pupa is pale and soft; the pupal period is from 7–11 days.

The adults are sexually dimorphic and quite distinct; the female has one dark spot in the centre of the yellow forewing, whereas the male has a series of small dark spots on a brown forewing. Body length is about 13–16 mm and the wingspan 22–30 mm, the males being smaller. The adults do not feed and only live for 4–10 days.

The entire life-cycle takes from 35–71 days.
Distribution. Recorded from Pakistan, India, Sri Lanka, through S.E. Asia, Indonesia, Philippines, up to China and S. Japan (CIE map no. A252).
Control. In some areas early or late planting is recommended so as to avoid crop continuity and a build-up of the borer population. Various other types of cultural control are practised in different countries, according to the local condition. A number of rice cultivars show general resistance to stem borers.

Chemical control is as for *Chilo polychrysus*.

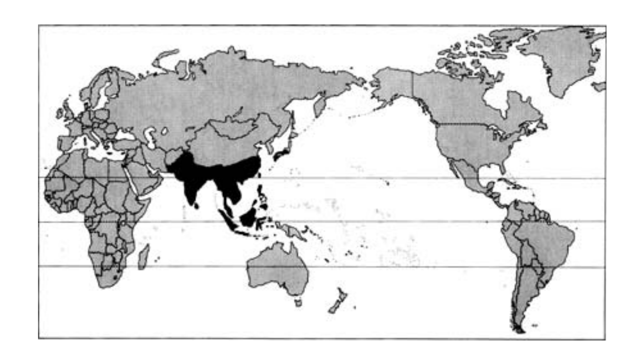
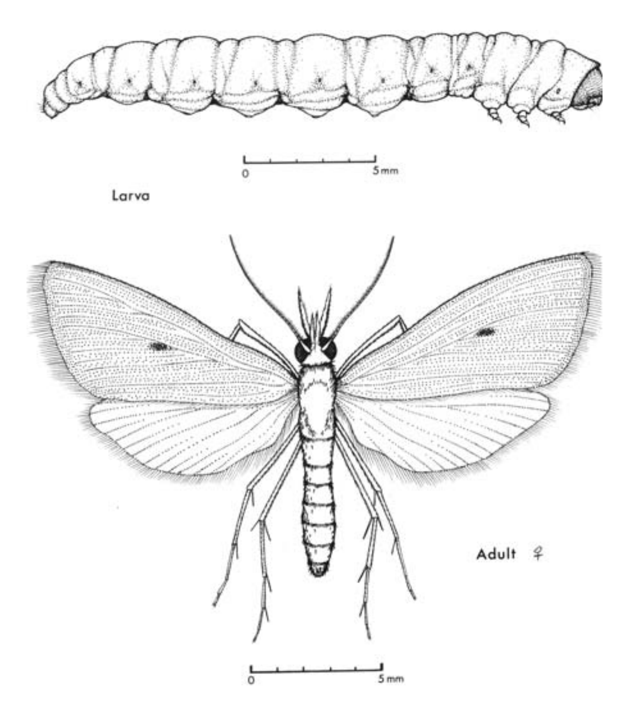


Fig. 9.286. Scirpophaga incertulas (Yellow Paddy Stem Borer); India.



Scirpophaga innotata Wlk.
(= *Tryporyza innotata* (Wlk.))

Common name. White Paddy Stem Borer
Family. Pyralidae
Hosts (main). Rice
(alternative). Wild rice and various wild grasses.
Damage. The caterpillars bore into the rice stems and hollow out the stem internodes and nodes. Attacked young plants show typical 'dead-heart' symptoms, and older plants often break where the stem is hollowed out, and lodging results.
Pest status. A serious pest of rice throughout S.E. Asia.
Life history. Eggs are laid in batches of 80–150 on the leaf sheath and covered with a mat of brown hairs taken from the anal region of the female moth. Incubation takes 4–9 days.

The caterpillars are white in colour with a black head capsule, and are 18–25 mm long when fully grown. Larval development takes from 19–31 days.

Pupation takes place inside the rice stem, and the pupa is pale and soft; the pupal period takes 7–11 days.

The adult of this species does not have any dark spots on the forewings at all, in either sex; body length is 13–16 mm and wingspan 22–30 mm, the male being smaller.

The entire life-cycle takes 30–51 days and there are usually several generations per year.
Distribution. Pakistan, India, Vietnam, Indonesia, Philippines, West Irian and N. Australia (CIE map no. A253).
Control. Several resistant varieties of rice are available, and a number of different cultural practices are used to lower borer populations.

Chemical control is as for *Chilo polychrysus*. Chemicals used include carbofuran, chlorpyrifos, phosalone, and cartap hydrochloride was very successful in India, formulated as granules.

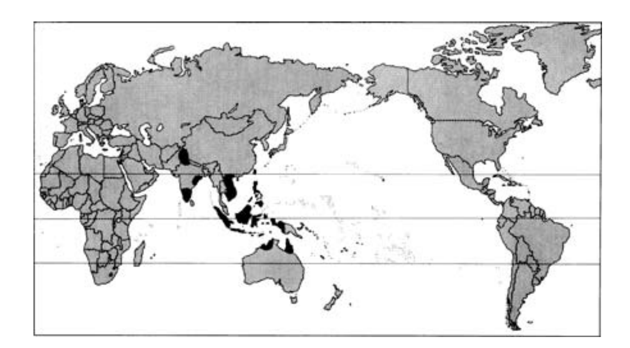
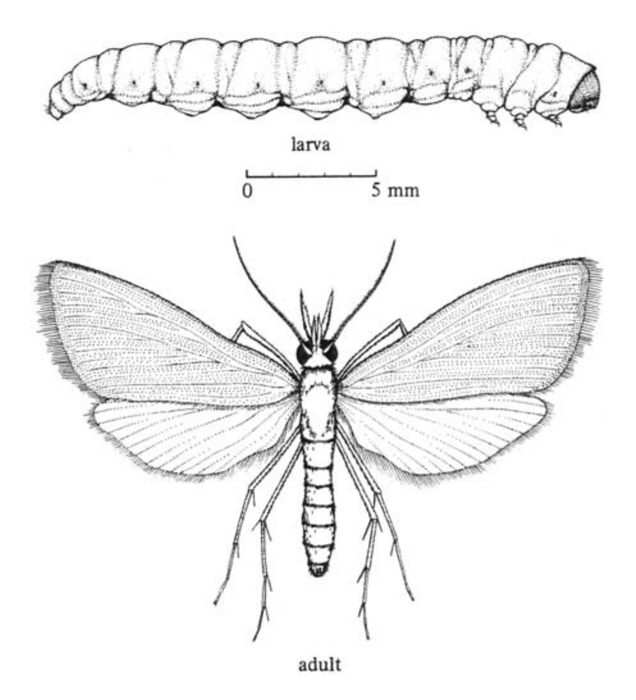


Fig. 9.287. Scirpophaga innotata (White Paddy Stem Borer); India.



Acraea acerata Hew.

Common name. Sweet Potato Butterfly
Family. Nymphalidae
Hosts (main). Sweet Potato
(alternative). Other species of *Ipomoea* (Convolvulaceae).

Damage. The caterpillars feed on the leaves of sweet potato, there often being several per leaf. Heavy attacks can result in complete defoliation of the vines often several times in succession, over wide areas. Defoliation in young plants causes crop retardation and large reductions in yield.

Pest status. A common and serious pest of sweet potato in eastern Africa.

Life history. The eggs are laid in batches of 100–150 on both surfaces of the leaves, and hatching takes about seven days. The eggs are pale yellow.

The larvae are greenish-black and covered with fleshy, branching spines. For the first two weeks of their life the caterpillars are gregarious, feeding on the upper leaf surface under a protective webbing. For the final week of larval life the caterpillars become solitary and nocturnal and eat the whole leaf lamina.

For pupation the caterpillars crawl away from the crop and climb up any convenient support; here in a vertical position, often several metres from the ground, the pupa is formed. The pupal period lasts for about seven days.

The adult butterfly is a pretty little nymphalid with orange and black wings and conspicuously knobbed antennae; wingspan is 30–40 mm.

Distribution. E. Africa and Zaïre only.

Control. Chemical control can usually be achieved by the use of DDT sprays, or malathion or fenitrothion.

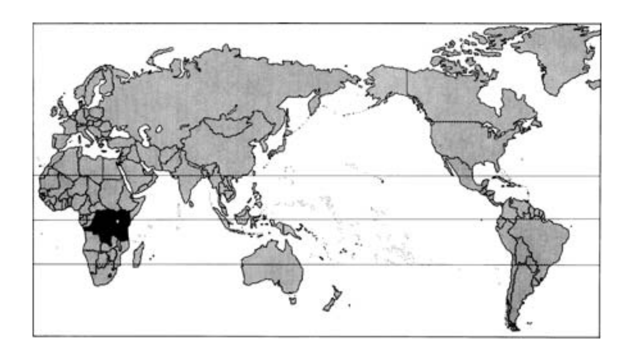
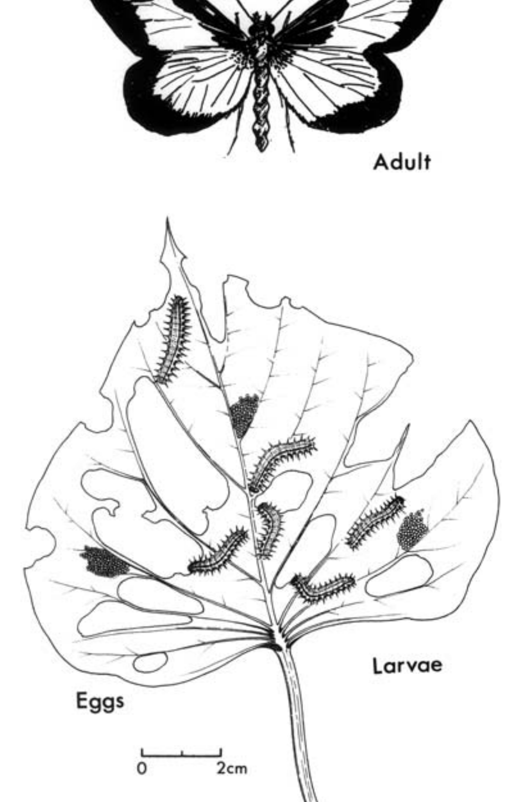


Fig. 9.288. Acraea acerata (Sweet Potato Butterfly); Kenya.



Chilades lajus (Stoll)

Common name. Lime Blue Butterfly
Family. Lycaenidae
Hosts (main). *Citrus* species
(alternative). Other members of the Rutaceae, especially *Atalantia, Fortunella,* and *Zanthoxylum* spp.
Damage. The caterpillar feeds on the flush leaves and young shoots, and is usually attended by ants, but damage is seldom serious.
Pest status. A widespread pest of *Citrus* in tropical Asia, but usually only of minor pest status.
Life history. Eggs are laid singly on to the flush growth, where they are stuck firmly to the leaf lamina.

The larvae are pale green, with faint dark markings running longitudinally along the body; at maturity they are about 20 mm in body length; They are attended by ants but are not dependent upon them.

Pupation takes place on the leaf surface, and the small rounded pupa measures about 14 mm.

The adults show sexual dimorphism in that the male is blue-coloured, but the female is brownish with blue infuscation on the inner parts of the wings; both are greyish-coloured underneath with a series of dark markings; there are no 'tails' on this species. Body length is about 8–10 mm and wingspan 20–24 mm; there are distinct wet-season and dry-season forms.

There are several generations per year.
Distribution. Sri Lanka, India, Malaya (North), Philippines, and S.E. Asia up to S. China.
Control. Usually not required.

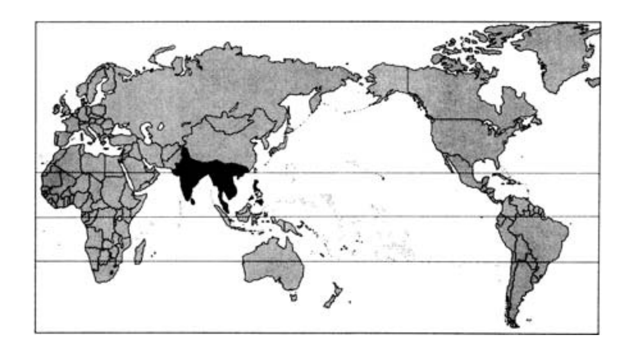
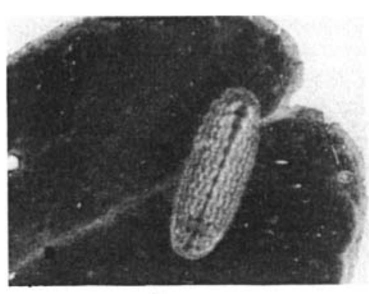
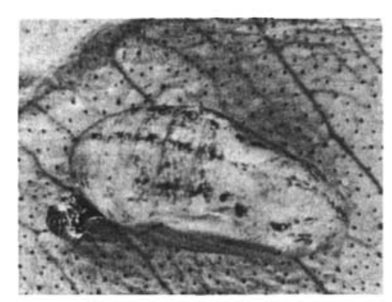


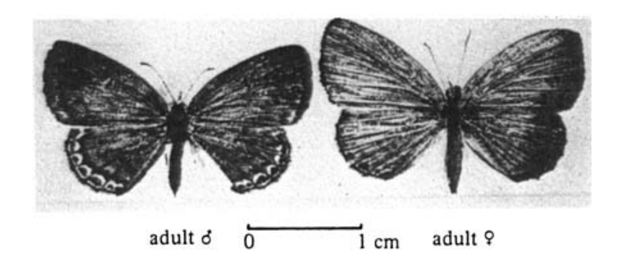
Fig. 9.289. Chilades lajus (Lime Blue Butterfly); S. China.



larva



pupa



Lampides boeticus (L.)

Common name. Pea Blue Butterfly (Long-tailed Blue)
Family. Lycaenidae
Hosts (main). Various pulse crops
(alternative). Cultivated and wild species of Leguminosae.
Damage. The larva feeds inside the pods, eating the young seeds; on small pods the larvae makes a hole in the pod wall in order to reach the seeds.
Pest status. A widespread pest of legumes, commonly encountered, but not often a serious pest.
Life history. Eggs are laid singly on the shoots, on or near the young flowers, and the young caterpillar feeds first inside the flower and then on the young pod. A crop with large pods will have the larvae inside the pods eating the seeds, but in crops with small pods the caterpillars eat holes in the sides of the pods predominantly brown with a blue infuscation near the body; both sexes have small 'tails' on the trailing edge of the hindwings – one tail per wing, and each about 2–3 mm in length. The female illustrated had lost her 'tails'. On the hindwing by the 'tail' are two small eyespots which show on both sides of the wing. As with many other blues, these butterflies sit at rest in a 'head-down' position so that the 'tails' simulate antennae and the eyespots simulate eyes, thus creating the impression that the insect is facing in the opposite direction, and presumably misleading would be predators. The larva is green in colour and blends well into the general colour of the foliage. Pupation takes place on the plant foliage.

The adults show distinct sexual dimorphism in that the upper surface of the male's wings are bright blue (with a dark distal fringe) but the female is basically brown.
Distribution. S. and C. Europe, Africa, through India and S.E. Asia up to S. China, throughout Australasia, New Zealand and Hawaii (USA). Not yet recorded from the American mainland.
Control. Generally not required as the populations of this species seldom reach economic injury level.

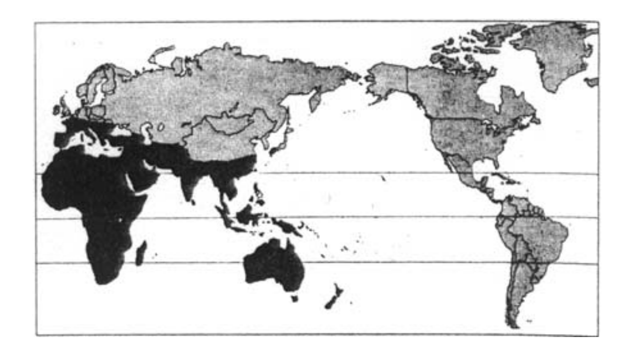
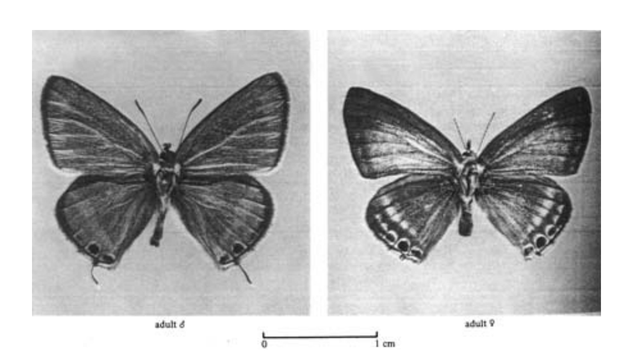


Fig. 9.290. Lampides boeticus (Pea Blue Butterfly); S. China.



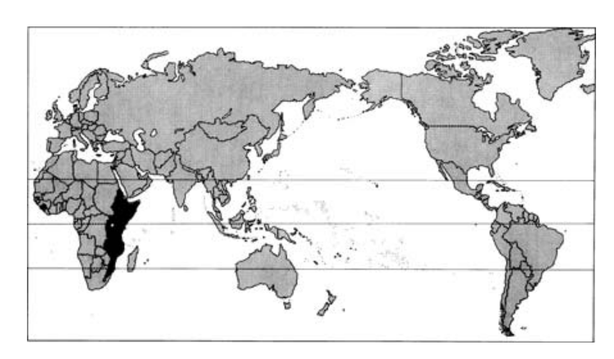




Virachola bimaculata (Hew.)
(= *Deudorix lorisona* Hewitson)

Common name. Coffee Berry Butterfly
Family. Lycaenidae
Hosts (main). Coffee (*arabica* and *robusta*)
(alternative). Various wild Rubiaceae.
Damage. Single holes are bored into the sides or ends of large green berries. Later the berries turn brown and the edges of the holes bend up to form a distinct rim. Many affected berries are shed. The damaged berry is hollowed out and is clean inside, since the caterpillar pushes its excreta out through the entrance hole. Both beans are usually eaten.
Pest status. Normally only a very minor pest of *arabica* coffee but occasional severe outbreaks have occurred – especially at higher altitudes. It is only recorded from *arabica* coffee. The E. and W. Rift forms of the butterfly in Kenya have slightly different markings and may be different races.
Life history. The eggs are spiny, and are laid singly, stuck to the sides of berries.

The larva is a green caterpillar with brown markings which grows to a length of about 20 mm before pupating. It probably eats out several berries before reaching maturity.

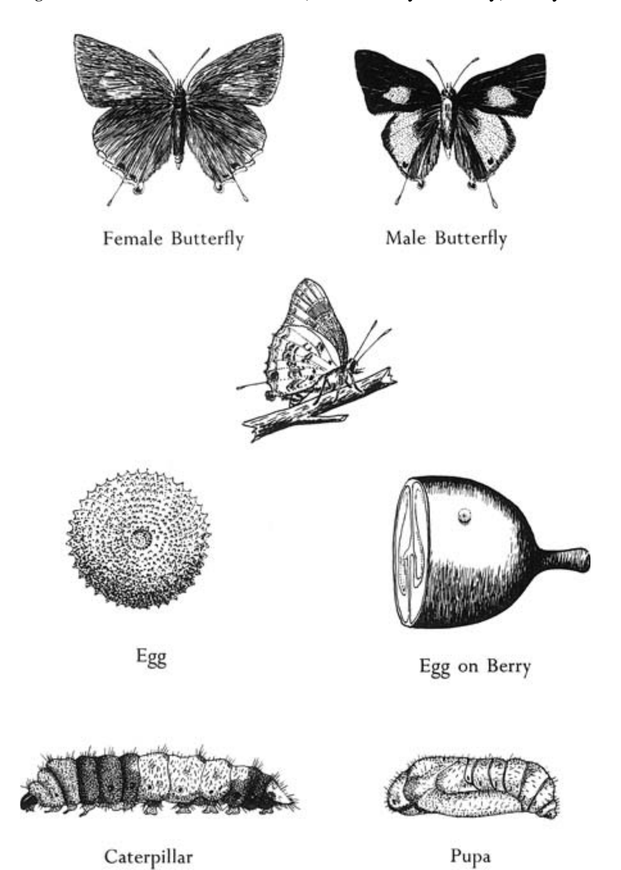


Pupation usually takes place in a chamber hollowed out in dead wood. The rotting surface where an old vertical stem has been cut off is a favourite site. The pupa is brown, rather squat in appearance and about 14 mm long. The pupal period is about one month.

The male butterfly has wings which are grey below and nearly black above with bold orange-red markings. Its wingspan is a little more than 20 mm. The female has wings which are generally grey on both surfaces; its wingspan is more than 25 mm. Both sexes have delicate, tail-like prolongations of the hindwings.
Distribution. Eastern Africa and Sierra Leone. In Ethiopia the Coffee Blue Butterfly is recorded as *Deudorix lorisona*, found on *arabica*.
Control. Attacks are rarely reported until too late for effective action, so no insecticidal trials have been performed. Scouting for eggs may be worth while.

Since the attack is normally confined to a small area it is suggested that as a foliar spray or dust fenitrothion, chlorpyrifos, deltamethrin could be effective. .

Fig. 9.291. Virachola bimaculata (Coffee Berry Butterfly); Kenya.



Pieris canidia (L.)
(= *Artogeia canidia* (L.))

Common name. Small White Butterfly
Family. Pieridae
Hosts (main). *Brassica* species.
(alternative). Other members of the Cruciferae such as nasturtium, and a few other plants.
Damage. The larvae feed singly, usually deep in the cabbage heart, making holes in the leaves, with frass accumulation; so much damage may be overlooked by casual inspection.
Pest status. A serious pest of *Brassica* crops in S.E.Asia and India, often occurring as a mixed infestation with other species of *Pieris* (e.g. *P. brassicae* and *rapae* in N. India); a small amount of damage is important as it is usually in the heart of the plant.
Life history. Eggs are laid singly on the host leaves (as opposed to the clusters laid by the larger *P. brassicae*), and the solitary caterpillars prefer to feed in the cabbage heart where they are offered more protection. The caterpillar is green with many tiny spots and fine setae so that it has a velvety appearance. There is a narrow yellow line dorsally along the back. Mature larvae are about 25 mm in length.

Pupation takes place in an upright pose with a band of silk around the thoracic region holding the chrysalis in position; the cremaster at the end of the abdomen rests upon a small pad of woven silk. The larvae often crawl off the host plant on to a firm substrate and can be found pupating on walls, fences and trees.

The adults are typical white butterflies, showing distinct sexual dimorphism, the male does not have the two black spots on the upper surface of the forewings, although they are present on the undersides of the wings. Also the marginal black spots on the hindwings are larger in the female. Wingspan is about 5–6 cm.

Breeding is continuous in the warmer regions and there may be eight generations per year; each generation taking as little as 20 days. In more northern regions overwintering occurs in the pupal stage and the winter generation may last for three months.
Distribution. India, S.E. Asia, to S. China, Taiwan and the Philippines.
Control. Natural levels of predation and parasitism are usually high in most countries, but if chemical control is required then DDT, trichlorphon, or mevinphos, either as dusts or sprays, can be used. Care must be taken to apply the insecticide to the heart region of the plant, and extra wetter may need to be added to sprays to overcome the waxy nature of the plant cuticle.

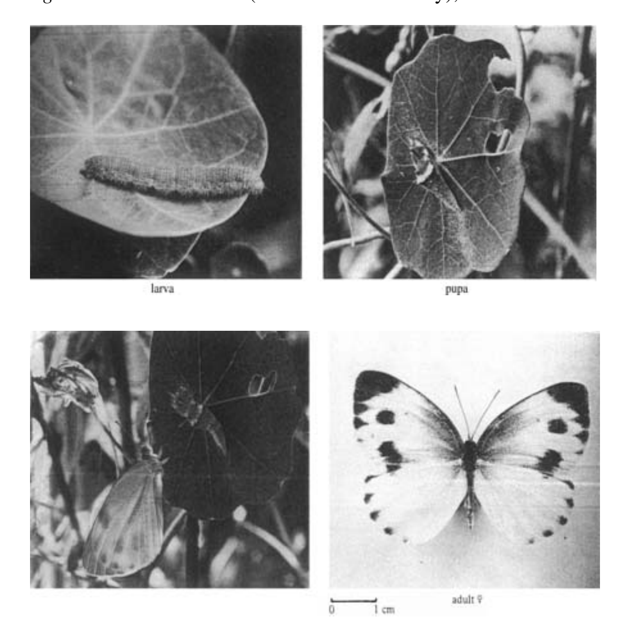


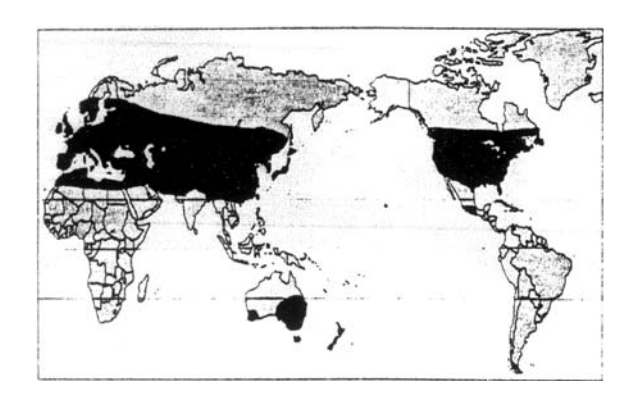
Fig. 9.292. Pieris canidia (Small White Butterfly); S. China.

Pieris rapae (L.)

Common name. Small White Butterfly (Imported Cabbageworm)
Family. Pieridae
Hosts (main). *Brassica* species.
(alternative). Cultivated and wild Cruciferae.
Damage. The caterpillars eat the leaves, and in heavy infestations they cause partial defoliation; but they are more solitary than *P. brassicae* so, although this pest species is generally more abundant, individual plant damage is usually less.
Pest status. A very serious, common and widespread pest of cruciferous crops worldwide; damage is often serious in that the 'heart' of the plant is preferred; faecal contamination is also an important factor.
Life history. Eggs are laid singly on the host plants, generally over a wide area; these butterflies are not confined to sheltered gardens and headlands, so entire commercial crops may be infested. Most eggs are laid on the underneath of leaves, as early as March and April; hatching requires about two weeks.

The caterpillar is green with many small setae and a yellow dorsal line, and it has a velvety appearance; fully grown it is about 25 mm long. There are often several caterpillars on the same leaf, although they are not at all gregarious: they apparently prefer to feed in the 'heart' of the cabbage.

Pupation takes place usually on the plant, and there is a typical pierid chrysalis coloured greenish-brown. Pupation takes place in June and July.

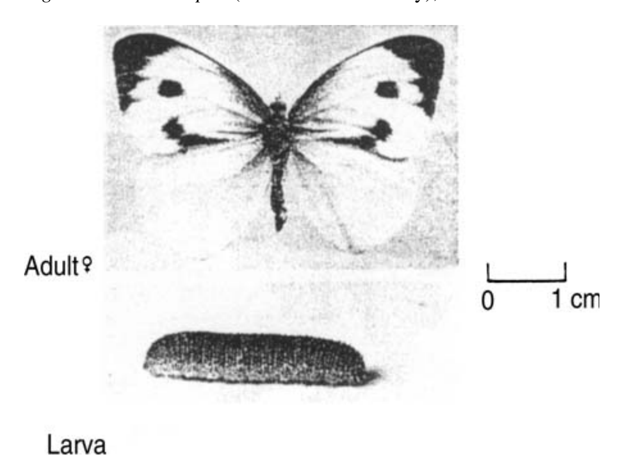


Second-generation adults emerge over a long period from July to September, and the pupae of this generation overwinter. Most damage is done by the second-generation larvae. Generally a bivoltine species in the UK, but has eight generations annually in Israel; under warm conditions breeding could be continuous.

The adults are typical 'white' butterflies, wingspan 40–5 mm; the female has spots on the forewing and the male does not.
Distribution. This species is widespread throughout Europe and much of Asia, and N. Africa, (down to the Tropic of Cancer); now introduced into Australia, New Zealand, Hawaii, Canada, USA and Mexico (CIE map no. A. 19). In N. America a regular migrant, flying north during the warm summer period.
Pieris napi (L.) – (Green-veined White Butterfly) not scarce but more common on wild hosts.

A few other species (different genera) of Pieridae have larvae that also feed on Cruciferae, but these are mostly rather rare or uncommon, and seldom found.
Control. As for *Pieris brassicae*; also heavily parasitized by *Apanteles glomeratus* and *Pteromalus puparum* (as with *P. brassicae*), and the braconid *Meteorus versicolor*, so care has to be taken when applying insecticides.

Fig. 9.293. Pieris rapae (Small white Butterfly); S. China.



Papilio demodocus Esp.

Common name. Orange Dog
Family. Papilionidae
Hosts (main)**.** *Citrus* spp.
(alternative). Other species of Rutaceae.
Damage. The caterpillars defoliate the trees; all stages feed at the edge of either flush or hard leaves.
Pest status. This pest is universally present on all species of *Citrus* in the Old World. It is usually only a minor pest of mature trees but severe attacks are quite common in nurseries and on small trees.
Life history. The eggs are pure white or have black bands or patches; spherical, and just over 1 mm in diameter; they are laid singly on flush leaves and hatch after about four days.

The caterpillar has five instars; the first three are dark brown with white markings and resemble bird droppings; the fourth and fifth instars are pale green caterpillars with black, brown and grey markings. If the caterpillars are disturbed they shoot out a pink Y-shaped organ from just behind the head. Fully grown caterpillars are 5 cm or more long. The larval period lasts about 30 days.

Pupation takes place on a small branch; the posterior end of the pupa touches the branch but the anterior end is about 10 mm away and connected to it by strands of silk. The pupa varies in colour from yellowish-green to brown and is about 3 cm long. The pupal stage lasts about 14 days.

The adult is a handsome swallowtail butterfly often seen feeding on the nectar of various flowers. The general colour is dark brown with numerous pale yellow markings.
Distribution. Africa.
Control. Hand collection of the caterpillars is often effective on small trees. Otherwise, chemical control can be achieved using foliar sprays, applied to run-off, of malathion, fenthion or fenitrothion.

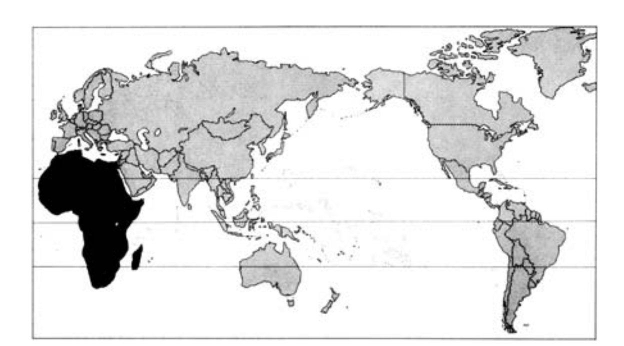
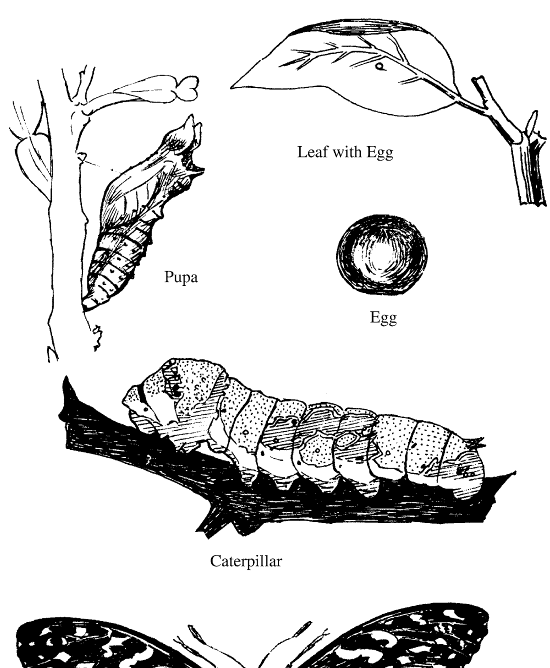
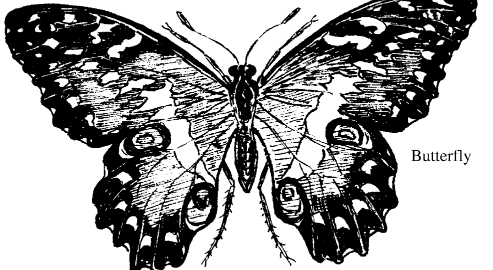


Fig. 9.294. Papilio demodocus (Orange Dog); Kenya.





Papilio demoleus L.

Common name. Lemon Butterfly (Citrus Swallowtail)
Family. Papilionidae
Hosts (main). *Citrus* species
(alternative). Other members of the Rutaceae; *Zizyphus*, and bael fruit.
Damage. The larvae eat leaves, especially flush growth, and young plants may be defoliated.
Pest status. A widespread pest of *Citrus* throughout tropical Asia and Australasia, together with the other species of *Papilio* (see next page). A serious pest of young trees, but usually only a minor pest of mature trees.
Life history. The eggs are pale yellow and laid singly on flush growth, usually at the tips of the leaves or at the edge of the lamina. Hatching takes about four days.

The young larvae look remarkably like bird droppings for the first three instars, then the bright green coloration develops with the bands and spots that enable each species of *Papilio* to be identified at this stage. Full-grown caterpillars measure up to 5 cm at the end of about 30 days growth.

Pupation takes place on a branch or twig, in an upright position, with the typical band of silk around the thorax to retain the chrysalis in that position. Pupation takes about 14 days.

The adult is a beautiful, tail-less swallowtail butterfly with a wingspan of 9–10 cm.

Usually 4–5 generations per year, maybe more in the hotter tropics. This is the Asian version of the African *Papilio demodocus* and to the non-taxonomist the two species appear the same; apparently several subspecies of both can be recognized in different parts of their range.
Distribution. Saudi Arabia, through Pakistan, India, S.E. Asia up to S. China and Taiwan, and parts of Australia, Papua New Guinea and West Irian (CIE map no. A396).
Control. See *P. demodocus*.

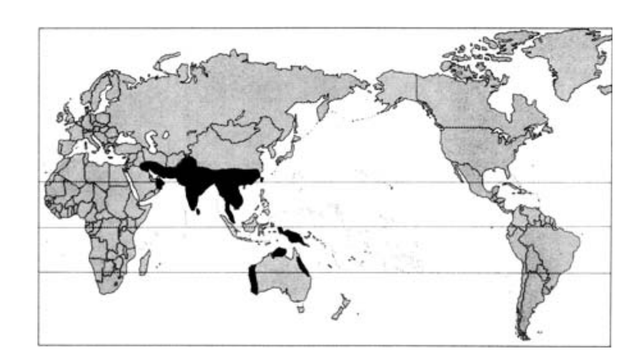
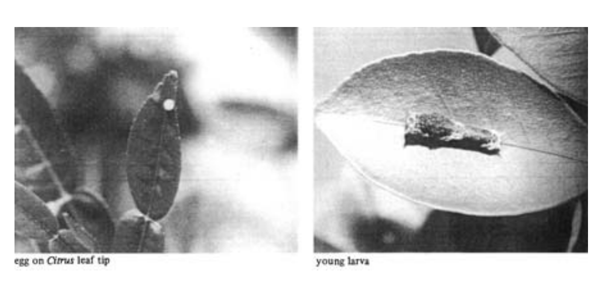
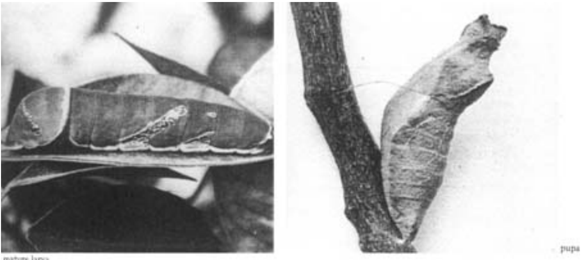
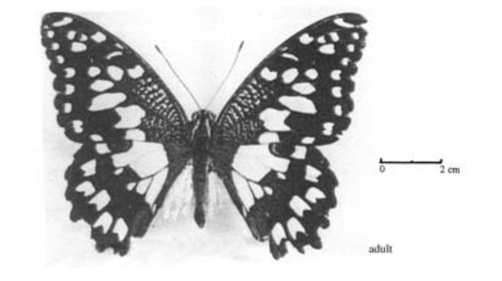


Fig. 9.295. Papilio a. (Lemon Butterfly); S. China.



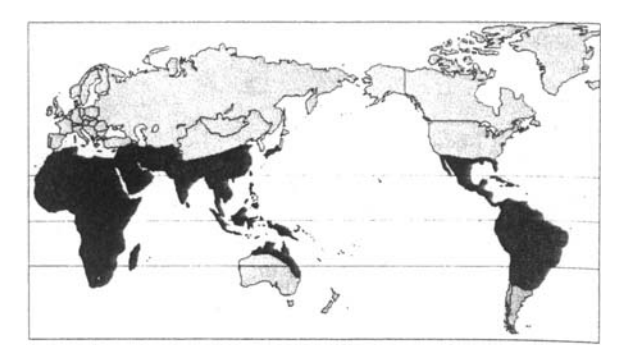




Papilio spp.
helenus L.
memnon L. } etc.
polytes L.

Common name. Citrus Swallowtails
Family. Papilionidae
Hosts (main). *Citrus* spp.
(alternative). Other members of the Rutaceae, and a few other plants.
Damage. The larvae eat leaves, especially flush growth, and despite being solitary they are often present in numbers large enough to defoliate young trees.
Pest status. *Papilio* spp. occur on *Citrus* wherever it is grown throughout the world, and their feeding damage is always noticeable, but seldom serious unless on young trees or in nurseries.
Life history. As with the previous two species, eggs are laid singly on the flush growth, but a laying female may well lay several dozen eggs scattered over one tree. The eggs hatch after a few days into small caterpillars that closely resemble bird droppings as they sit conspicuously on the leaf lamina. In the last two instars the larvae develop their individual specific body markings on a green background. There is some variation in these body markings, but experts claim to be able to recognize the different species of *Papilio* by the bands and spots on the body.

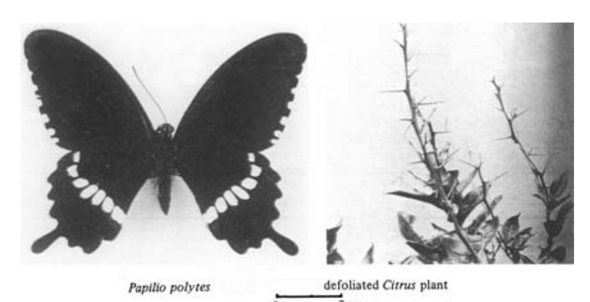
The pupae are indistinguishable generally, although there is some colour variation through different shades of green and brown.

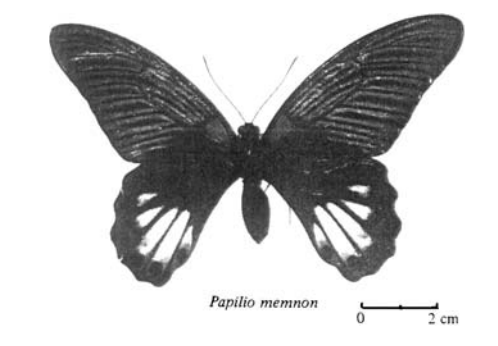


The adults are, of course, quite different in shape and coloration and also in size to some extent. On a pantropical basis there are some 10–20 species of *Papilio* to be found feeding on *Citrus* trees and bushes, and other Rutaceae; the African, Asian, Australasian and American species generally differ from each other. Within these broad distribution zones there are some minor differences; for example, there are some species in India that do not occur in S. China.
Distribution. These 10–20 species of *Papilio* are completely pantropical in distribution, although separated into species groups according to major geographical regions, as indicated above.
Control. Hand-picking is still recommended in many countries for removal of larvae in nurseries and from young trees.

For chemical control foliar sprays of malathion, fenthion or fenitrothion are recommended, applied to run-off.

Fig. 9.296. Papilio polytes and *P. memnon* (Citrus Swallowtails); S. China.

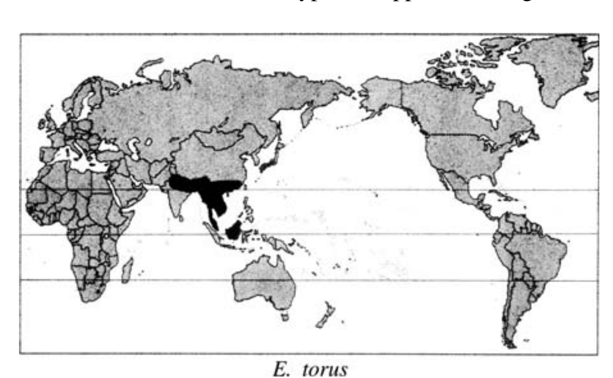




Erionota spp.
thrax (L.)
torus Evans

Common name. Banana Skippers
Family. Hesperiidae
Hosts (main). Banana
(alternative). Other members of the Musaceae; oil palm.
Damage. The larvae cut the leaf lamina and make individual rolls of leaf material in which they live, and grow, and eventually pupate, defoliation occurs.
Pest status. Usually a widespread but minor pest in S.E. Asia, but occasionally very heavy infestations occur and result in crop defoliation.
Life history. Eggs are laid in small clusters stuck on to the leaf lamina. The larvae is a typical skipper in having a soft white body with vague segmentation, narrow neck and a round black head capsule; the body is covered with a fine waxy material. Pupation takes place within a large leaf roll.

The adult is a large brown skipper with yellow marks on the forewings, and, in life, bright shining eyes like small rubies; wingspan is about 7 cm.
Distribution. The two species are sympatric in Malaysia, S.E. Asia and Borneo; but *E. thrax* also occurs in Java, Sumatra, and the Philippines, and *E. torus* also occurs in N. India and S. China, Japan.
Control. Generally not required in most situations, which is fortunate as it would be difficult to reach the insect larvae with conventional sprays; in emergencies, however, the usual insecticides effective against caterpillars could be used, with extra wetter added because of the wax on their bodies.



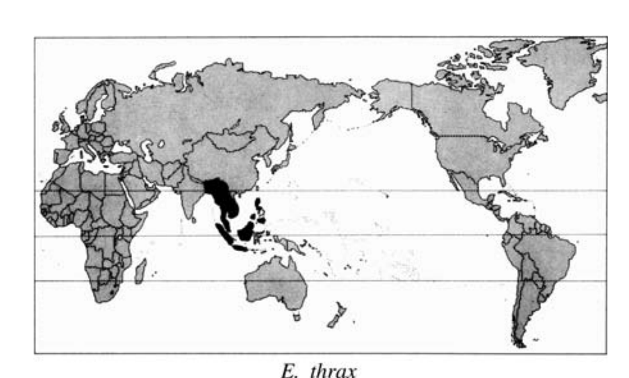
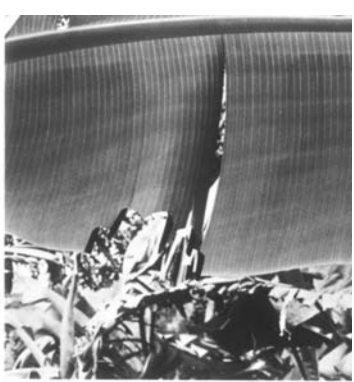


Fig. 9.297. Erionota spp. (Banana Skipper); S. China and Malaysia.

Eggs





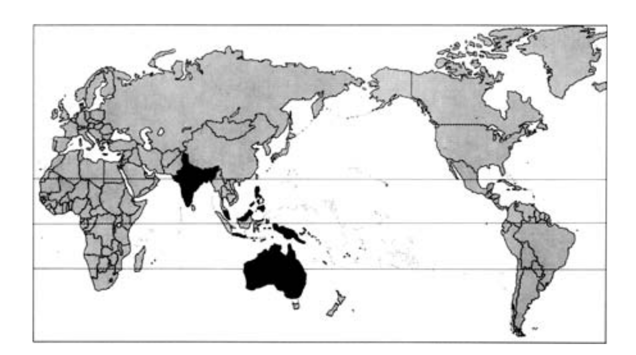




Telicota augias (L.)

Common name. Rice Skipper
Family. Hesperiidae
Hosts (main). Rice
(alternative). Sugarcane and bamboo.
Damage. Damage is done by the caterpillars feeding on the leaves, from the margin inwards towards the midrib, which is usually left intact, and also by tying the leaf edges together to form a tube or roll. The caterpillars live inside this roll. Damage is more severe on young transplanted seedlings which may fail to recover.
Pest status. Only occasionally a pest of any real importance, and then usually only on young transplanted seedlings.

Several other species of *Telicota* and several other genera of skippers are minor pests of rice in S., E. and S.E. Asia, and they are all quite similar to *T. augias* in appearance.
Life history. The eggs are laid singly on the leaves; they are pale yellow, and hatch in three days.

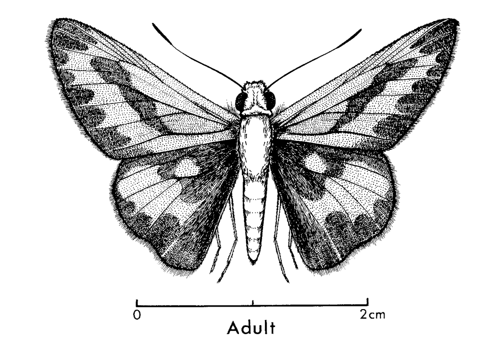


The caterpillars are pale green with a dark head and dark spot on the anal flap, and nocturnal in habit. They are fully grown in 20–25 days, after reaching a length of 40 mm.

Pupation occurs in the leaf tube; the pupa is pale yellow-green, and takes 8–10 days for development to be completed.

The adult skippers are orange-brown with brown wing markings, and have the characteristic large head and clubbed antennae with recurved tips, typical of the Hesperiidae.
Distribution. India, Bangladesh, Malaysia, Java, Philippines, Papua New Guinea, West Irian and Australia. As already mentioned there are quite a few other Skippers on rice throughout S.E. Asia, most of similar appearance.
Control. Control is similar to that for the rice leaf-rollers as they are similar in habits. Contact poisons such as dieldrin, carbaryl, and BHC as foliar sprays have given very satisfactory control.

Fig. 9.298. Telicota augias (Rice Skipper); Malayasia.



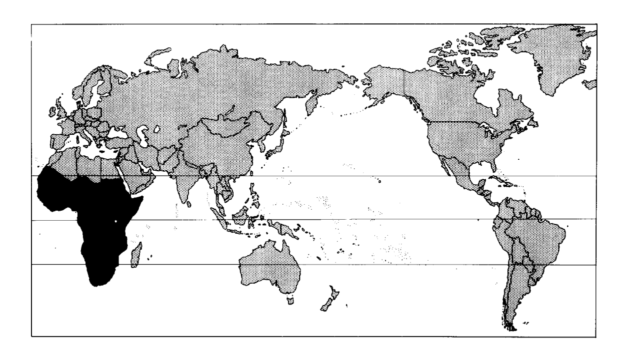


larval leaf roll

Epicampoptera spp.

marantica Tams
andersoni Tams

Common name. Tailed Caterpillars
Family. Drepanidae
Hosts (main). Coffee: *arabica* and *robusta*.
(alternative). None recorded.
Damage. The young caterpillars feed on the under surface of the leaf about half-way between the midrib and the edge. The upper surface of the leaf is left intact. The older caterpillars feed at the edge of the leaf sometimes eating everything except the midrib. If the tree is completely defoliated they will eat the berries and the green bark.
Pest status. *E. andersoni* is normally a minor pest of *arabica* coffee but severe outbreaks sometimes occur. Generally, *robusta* coffee is attacked by the species *E. marantica*. Three species are known from coffee in Africa.



Life history. The eggs are small, oval, usually laid singly; incubation takes 8–9 days.

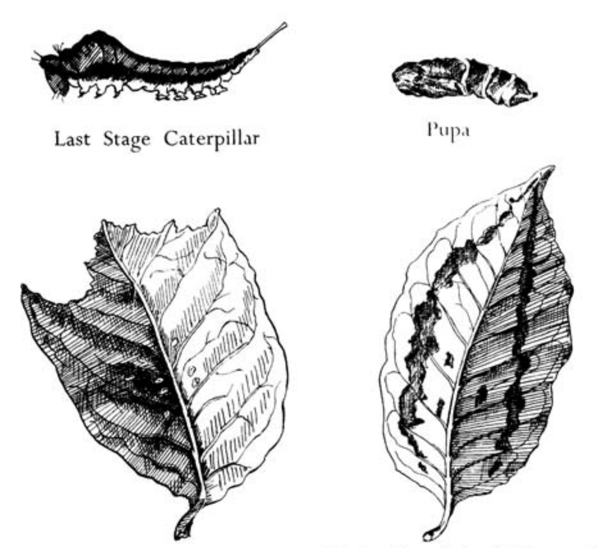
The larva is an easily recognized caterpillar, having a humped appearance due to the large thorax and the abdomen tapering to a thin tail. The colour is variable but the caterpillars are usually green when young, becoming purple or velvety brown when older. Fully grown, they are about 55 mm long. The caterpillar stage lasts for about four weeks.

The fully grown caterpillar rolls a leaf up into a cone, closes the open end with a pad of silk and pupates inside. The pupal period lasts about two weeks.

The adult moth is silvery grey to dark brown or mottled black in colour. The wingspan is about 40 mm. In the daytime it rests on the underside of leaves. Egg-laying occurs at night; each female moth lives for about six days and lays more than 500 eggs.
Distribution. Most parts of Africa.
Control. Chemical control can be achieved by foliar sprays of either fenitrothion or fenthion.

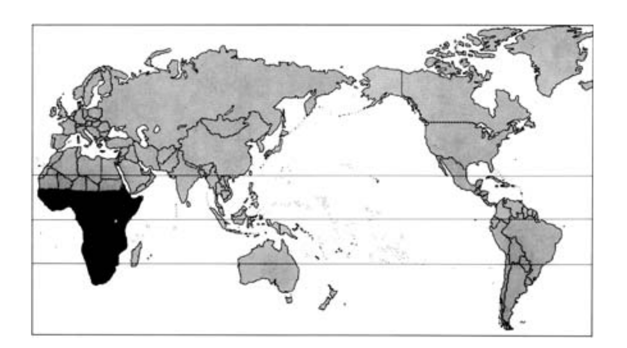
Fig. 9.299. Epicampoptera andersoni (Tailed Caterpillar); Kenya.





Ascotis selenaria (D. & S.)

Common name. Giant Looper/Citrus Looper
Family. Geometridae
Hosts (main). Coffee, Citrus
(alternative). Many other plants – 78 host species are recorded in S. Africa.
Damage. Young caterpillars chew pits in the upper leaf surface; older caterpillars chew circular holes right through the leaf. The oldest caterpillars eat at the margin of the leaf leaving a jagged edge. They also feed on the other green parts of the plant, flower buds, young berries, terminal shoots and the bark of sucker stems. If the terminal point is damaged, there may be fan-branching and growth distortions.
Pest status. This has been a minor pest of *robusta* coffee in Uganda for many years and has become a major pest of *arabica* coffee in Kenya recently, after very frequent use of parathion in coffee plantations – the caterpillars are not particularly susceptible to parathion but the predators and parasites are.



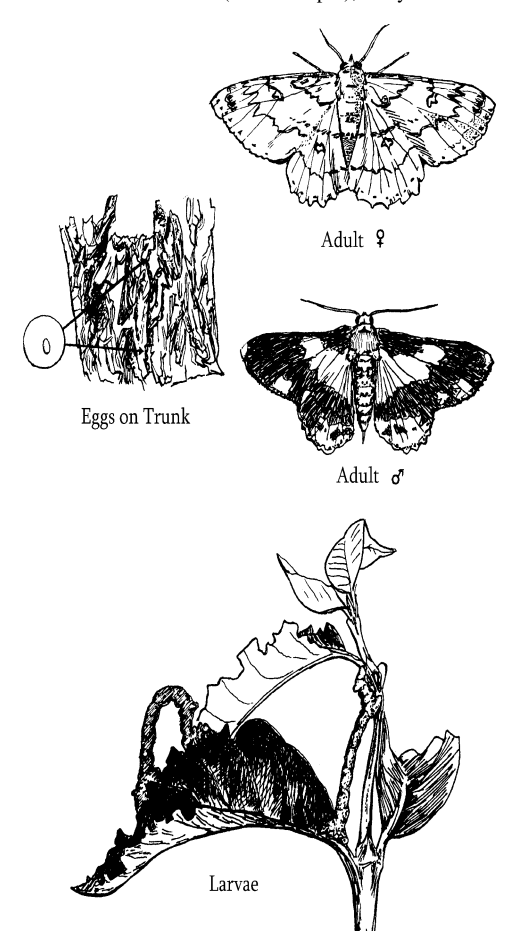
Life history. The eggs are pale blue-green, oval, about 0.7 mm long. They are laid in crevices in the bark, in clusters. Hatching takes about 7–10 days.

There are usually five larval instars, taking about 25–42 days. The caterpillar is a typical geometrid (looper) having only one pair of prolegs (in addition to the terminal claspers), and they move in the typical looping motion. The colour varies from pale grey to dark brown. Fully grown, the caterpillar is about 5 cm.

Pupation takes place in the soil; the pupa is shiny brown, and 18–20 mm long; pupation takes 14–21 days.

The adult is a night-flying moth, with a wingspan of 5 cm; colour is variable but is commonly pale grey with many dark grey markings. Egg-laying starts 1–2 days after emergence, and each female may lay about 2000 eggs; the females usually live for about 14 days.
Distribution. Africa South of the Sahara. Similar loopers are found on Citrus and other plants throughout S.E. Asia.
Control. Chemical control can be effected using foliar sprays of methomyl, fenitrothion, fenthion, etc.

Fig. 9.300. Ascotis selenaria (Giant Looper); Kenya.



Leucoplema dohertyi (Warr.)

Common name. Coffee Leaf Skeletonizer
Family. Epiplemidae
Hosts (main). Coffee, all species.
(alternative). None recorded.
Damage. The larvae feed on the undersides of leaves, usually near the midrib. Everything except the veins and upper epidermis is eaten, leaving irregular lace-like patches in the leaf.
Pest status. This pest attacks all cultivated species of coffee. It is usually a minor pest but severe outbreaks sometimes occur, especially in nurseries.
Life history. Eggs are laid singly or in small groups mostly on the underside of the leaf. Patches of old Skeletonizer damage are a favoured site. They are yellow-green, dome-shaped, and about 0.5 mm in diameter. Hatching takes about seven days.

The larva is a grey or white caterpillar with many pimple-like projections on its body. The larval period is about three weeks. On the day prior to pupation the caterpillar turns red; it is then about 10 mm long.

The mature caterpillar lowers itself on a silken thread and pupates in the ground. The pupal period lasts for about three weeks.

The adult is a grey and brown moth with a wingspan of about 14 mm. It is found resting on leaves during the day with the hindwings drawn back alongside the body and the narrow forewings held at right angles to the body.
Distribution. E. Africa, Zaïre, Ghana, Angola, Congo.
Control. Chemical control of this pest can be achieved with either fenitrothion or fenthion, as foliar sprays, the amount of spray used varying with the amount of leaf on the tree.

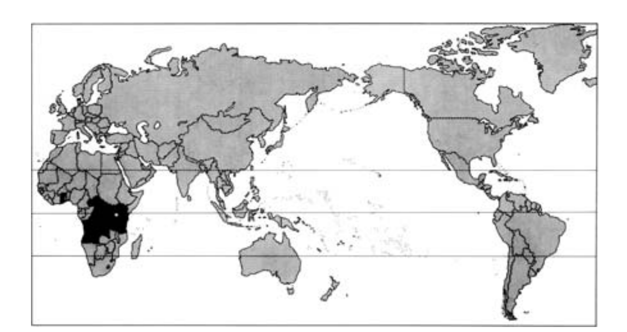
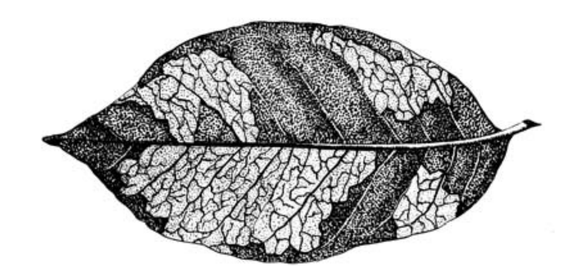


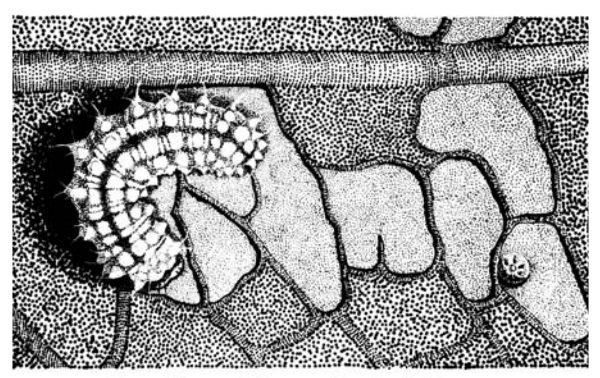
Fig. 9.301. Leucoplema dohertyi (Coffee Leaf Skeletonizer); Kenya.



Adult Moth – Natural Position



Damaged Leaf



Caterpillar and Egg on Patch of Damage

Attacus atlas (L.)

Common name. Atlas Moth
Family. Saturniidae
Hosts (main). Cinnamon, Citrus

(alternative) Cashew, coffee, guava, mango, tea, and other Lauraceae including camphor; also *Sapium* and *Schefflera* trees in the forests.

Damage. The larvae are leaf-eaters and because of their large size a small population may defoliate small trees.

Pest status. A serious pest of cinnamon in parts of Malaysia; elsewhere generally only a minor pest.

Life history. Eggs are laid in batches on the leaves of the host plant, and the young caterpillars soon disperse generally over the plant. There are five larval instars and the mature caterpillars are very large (up to 10 cm in length), white and coated with a flaky white wax. There are dark lateral tubercles along the body and several rows of long white tubercles dorsally along the abdomen.

Pupation takes place within a large silken cocoon spun between two leaves.

The adult is probably the largest known moth and females may measure up to 25 cm in wingspan. They are completely nocturnal and will never be seen in flight during the day. The females of this family are well known for the copious quantities of sex pheromone produced by newly emerged virgins, and their 'calling' is so successful that males come from considerable distances (1–2 km).

There is usually only one generation per year, but there might be two in Malaysia.

Distribution. The genus occurs throughout the Old and New World tropics but this species is found through India, S.E. Asia and up to China.

Control. Usually control measures are not required; the larvae are so large and conspicuous that on small trees hand-picking would be feasible.

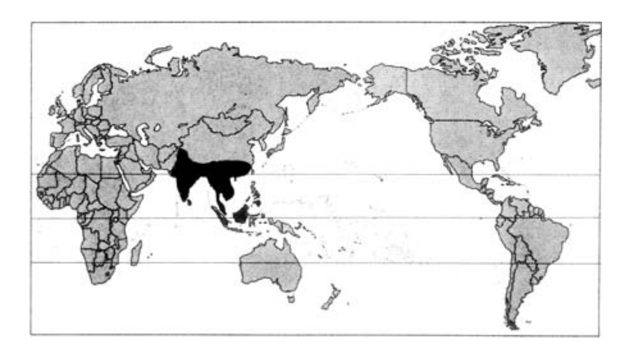
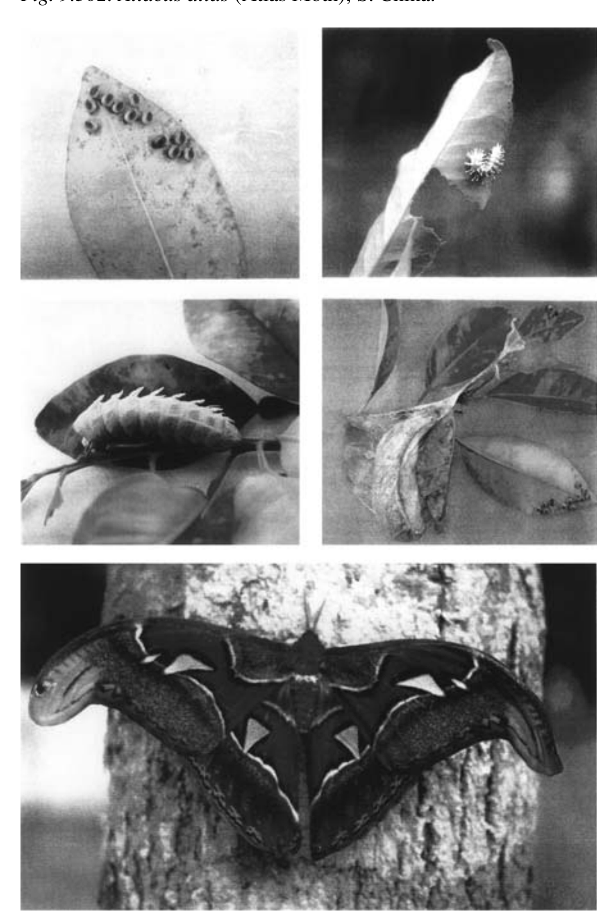


Fig. 9.302. Attacus atlas (Atlas Moth); S. China.



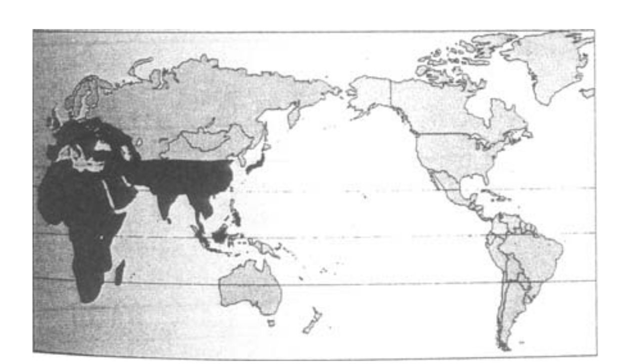
Acherontia spp.

Common name. Death's Head Hawk Moths
Family. Sphingidae
Hosts (main). Potato, tomato, eggplant, tobacco.
(alternative). Wild members of the Solanaceae; olive, sesame and some other plants.
Damage. The larvae eat leaves, and although solitary they are very large caterpillars so a small number can cause defoliation of the host plant. However, frequently there is only one larva per plant.
Pest status. Generally only a minor pest.
Life history. Eggs, often coloured reddish or blue, are laid singly on the foliage of the host plant – usually only one per plant.

The larva is white initially, with a yellow head and black 'horn', but when larger the colour is predominantly yellow, green or grey with diagonal blue stripes. The characteristic 'horn' on the last body segment, which gives all sphingid larvae the collective name of 'hornworms' in the USA, is the same colour as the body and is distinctly hooked dorsally at the tip. Mature larvae measure up to 10 cm in body length and larval development usually takes several months.

As with all Sphingidae pupation takes place in the soil in an earthen cocoon. In the more northern parts of its range it overwinters in the pupal stage and is univoltine. The length of the pupa is about 80 mm.

The adult is a large stout-bodied moth of striking appearance with long, dark forewings and short, yellow hindwings with black barring. The dorsum bears the skull-like marking from which it derives its common name. The abdomen is banded yellow and black. Body length is 50–55 mm and wingspan 8–12 cm. The natural resting position is shown in the top illustration. As with most other Sphingidae the adults are nocturnal in habits. This species is remarkable in that the adult moth can make a high-pitched chirping noise and is reputed to enter bee hives to steal honey.
Distribution. Europe, the whole of Africa, Middle East, India, S. E. Asia, China and Japan. *A. atropos* (L.) is the species found in Europe and more northern parts of Asia. *A. styx* (W.) occurs in India and S.E. Asia, does *A. lachesis* F.
Control. Generally not needed.



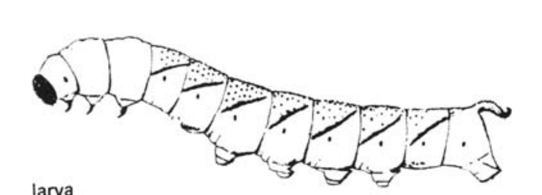


Fig. 9.303. Acherontia styx (Death's Head Hawk Moths); S. China.





Hawk moths and hornworms
(Lepidoptera; Sphingidae)

A small group of spectacular moths, found worldwide, 1000 species recorded; probably to be regarded as essentially a tropical group but quite well represented in temperate regions. The adults are distinctive with their tapering body, elongate forewings, and fast flight. They feed by taking nectar from flowers with a long calyx, by hovering in front of the flower. Most are nocturnal and fly to lights at night, but a few smaller species are diurnal and look rather like large bumble bees at flowers. The proboscis is usually very long, and up to 20 cm is not at all unusual.

The larvae are very large, stout-bodied caterpillars, with a smooth skin, and a characteristic terminal dorsal 'hook'. They are leaf lamina feeders and some are pests purely because of the quantity of food they consume. They are essentially solitary, but in some species there may be several to many larvae per plant and defoliation may result. Most species are fairly specific as to their diet, and the majority are restricted to a single host family for food, but a few pest species are truly polyphagous. The Solanaceae and Convolvulaceae are well-represented agriculturally as host plants for Sphingidae, but by far the most popular host is grapevine with more than a dozen hawk moths regularly recorded worldwide.

Pupation always takes place in the soil inside an earthen cell or in leaf litter, and the pupa always has the long proboscis clearly defined externally, sometimes quite separated from the rest of the pupal body. At the time of pupation sometimes the entire population of large caterpillars literally disappears overnight as they all descend to the ground and burrow into the soil.

Pest species of Sphingidae

Acherontia atropos (L.) – (Death's Head Hawk Moth) Solanaceae; Old World.
Acherontia styx (Westwood) – (Small Death's Head Hawk Moth) polyphagous?; Asia.
Agrius cingulatus (F.) – (Sweet Potato Hornworm) New World.
Agrius convolvuli (L.) – (Sweet Potato Hawk Moth) Old World, Hawaii (CIE map no. A.451).
Cephonodes hylas (L.) – (Coffee Hawk Moth) Africa, Asia, Japan.
Cressonia juglandis (J.E. Smith) – (Walnut Sphinx) USA.
Erinnyis spp. – guava and papaya; USA and S. America.
Eumorpha spp. – (Grapevine Sphinxes) USA.
Hippotion celerio (L.) – (Silver-striped Hawk Moth) polyphagous; S. Europe, Africa, S. Asia, Australia.
Hyles lineata (Esp.) – (Striped Hawk Moth) polyphagous; cosmopolitan (CIE map no. A.312).
Langia zeuzeroides Moore – deciduous fruit; N. India.
Manduca quinquemaculata (Haw.) – (Tomato Hornworm) Canada, USA, C. and S. America (see page 421).
Manduca sexta (L.) – (Tobacco Hornworm) Canada, USA, C. and S. America (see page 428).
Marumba gaschkewitschi (B. & G.) – (Peach Hornworm) China and Japan.
Paonias astylus (Drury) – (Huckleberry Sphinx) USA.
Smerinthus jamaicensis (Drury) – (Twin-spot Sphinx) USA.
Smerinthus ocellata (L.) – (Eyed Hawk Moth) Europe.
Smerinthus planus Wlk. – (Cherry Hornworm) Japan.
Sphinx spp. – (Fruit Tree Sphinxes) USA.
Theretra spp. – (Grapevine Moths) S. Europe, India, Asia, Japan.

Agrius convolvuli (L.)
(= *Herse convolvuli* (L.))

Common name. Sweet Potato Moth (Convolvulus Hawk Moth)
Family. Sphingidae
Hosts (main). Sweet Potato
(alternative). Other Convolvulaceae, and some Leguminoseae, for example *Phaseolus* spp. and *Glycine*; also sunflower, Citrus, Grapevine.
Damage. The larvae defoliate the plant.
Pest status. A very widespread species, common in Africa, but not usually a serious pest for the damage to the sweet potato plants is not extensive and the plants can tolerate some defoliation. It has been very serious in parts of India on beans.

It is known as the Convolvulus Hawk Moth in Europe.
Life history. The eggs are small for a sphingid, sub-spherical, 1 mm diameter, laid singly on any part of the food plant.

There are five larval instars, each with a conspicuous posterior 'horn' which gives the family its common name in the USA of 'hornworms'. The colour is variable, usually either greenish or brownish. Fifth instar caterpillars are large – up to 95 mm long and 14 mm broad. The larval period lasts 3–4 weeks.

Pupation takes place in the soil, some 8–10 cm down; pupal duration is variable, it may be 17–26 days or as long as 4–6 months according to the climate.

Adults are large grey hawk moths with black lines on the wings and broad incomplete pink bands on the abdomen. Wingspan is 80–120 mm. The adults are crepuscular in habits and feed on flowers, particularly those with a long tubular calyx (e.g. *Hibiscus, Ipomoea, Begonia*, etc.).
Distribution. Europe, most of Africa; Iran, India, Bangladesh, Burma, Malaysia, Indonesia, Australia, New Zealand, Papua New Guinea, West Irian, S. China and the Pacific islands. (CIE Map no: A.451).
A. cingulatus is the Sweet Potato Hornwarm the USA, C. & S. America.
Control. Should insecticidal treatment be required then dusts or sprays of TDE, or sprays of parathion, applied when the first signs of damage are evident, should be effective.

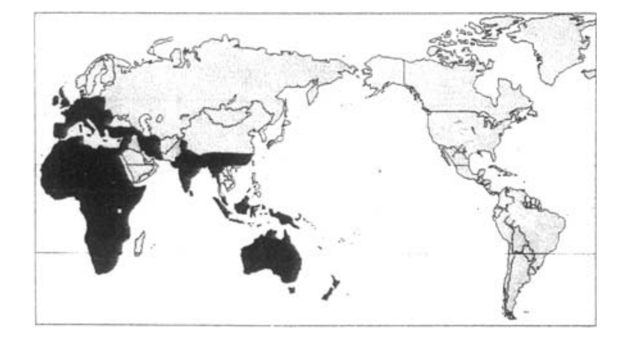
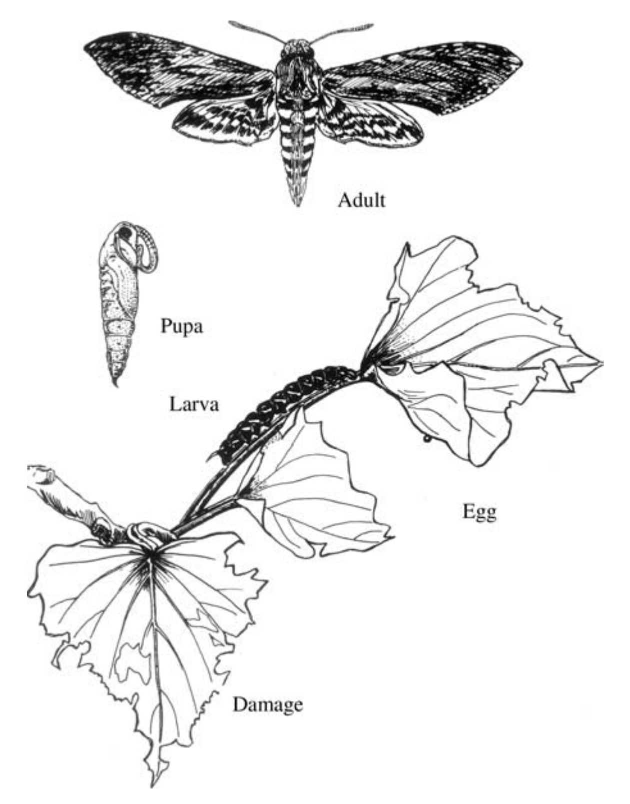


Fig. 9.303. Agrius convolvuli (Sweet Potato Hawk Moth); Kenya.



Cephonodes hylas (L.)

Common name. Coffee Hawk Moth (Bee Hawk Moth)
Family. Sphingidae
Hosts (main). Coffee
(alternative). *Gardenia*, and some other (but not all) members of the Rubiaceae.
Damage. The larvae eat leaves and in heavy infestations may actually defoliate the host tree (bush).
Pest status. A widespread species, frequently encountered, and usually only a minor pest; but in Malaya at the turn of the century it was a very serious pest.
Life history. Eggs are laid singly on the coffee leaves, and each female may lay about 90 eggs. Hatching occurs after three days.

The caterpillars are green laterally, with conspicuous red spiracles, a dorso-lateral stripe of white separates the green flanks from the blue-coloured back, and when mature they measure about 5–6 cm in length. Larval development takes 20–22 days.

Pupation takes place in the soil inside an earthen cocoon, at a depth of about 5 cm, or in the leaf litter at the base of the tree. Pupal development in Malaya takes some 12–14 days, but in China and Japan the pupa overwinters.

In the tropics there are several generations per year, but further north there are probably only one or two generations.

The adult is a smallish hawk moth with a wingspan of 5–6 cm and characteristic hyaline wings; it is one of the few diurnal species. The abdomen has a median red band on two segments followed by two yellowish segments. The species is quite distinctive.
Distribution. From W. to E. Africa, S Africa, India and Sri Lanka, through Malaysia and S.E. Asia, Indonesia up to China and southern Japan; also Queensland (Australia). (CIE map no. 471).
Control. At the present time control measures are normally not required for this species on coffee, but DDT or carbaryl should be effective.

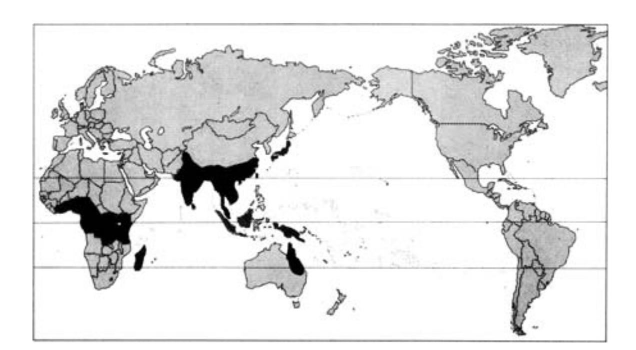
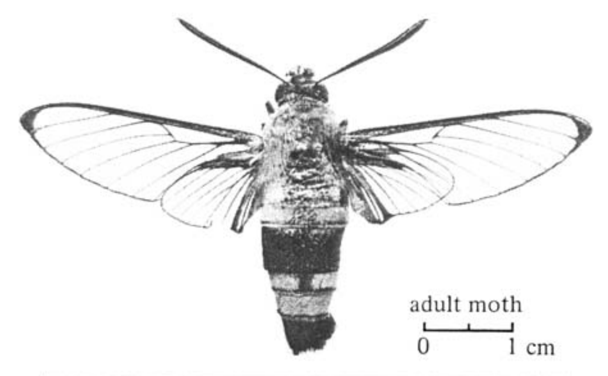
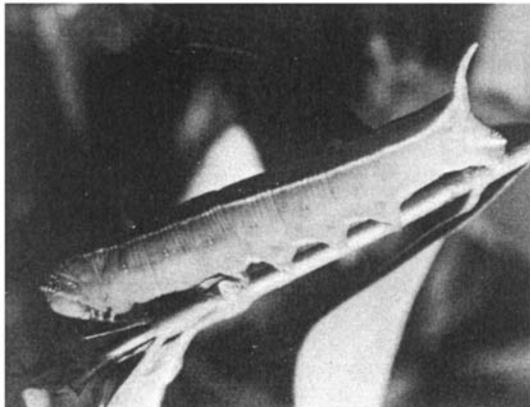


Fig. 9.304. Cephonodes hylas (Coffee Hawk Moth); S. China.





Hyles lineata (F.)

(= *Celerio lineata* F.)

Common name. Striped Hawk Moth
Family. Sphingidae
Hosts (main). Grapevine
(alternative). Cotton, olive, buckwheat, *Prunus* spp., sweet potato and others.
Damage. The caterpillars are leaf-eaters and cause a certain amount of defoliation, but since they are solitary damage is usually only slight, although one larva can eat many leaves.
Pest status. Generally only a minor pest, but widespread in distribution and quite frequently encountered in the field.
Life history. Eggs are laid singly on the plant foliage; they are green and about 1 mm in diameter.

The larvae are greyish or greenish, with a brown-coloured horn, and finally reach a size of about 7–8 cm, after about 25–35 days.

Pupation takes place in the soil inside an earthen cocoon, either in the soil or sometimes in the leaf litter.

The adult is basically brown above but more orange-rufous ventrally, with the hindwings conspicuously red and a red stripe laterally along the body, and a white stripe dorso-laterally along the thorax and head. The wingspan is 5–6 cm.

In warm climates one generation takes 30–40 days, but in Israel the winter generation requires seven months, or more. Southern Europe is generally too cold for this species to develop successfully, and most populations originate from spring migrants from North Africa which even reach as far north as southern England.
Distribution. S. Europe, N. Africa, E. and S. Africa, Middle East, India, China, Japan, parts of Australia, most of the USA, and parts of C. and S. America (CIE map no. A312). Within this range there are several recognized subspecies, and other closely related species.
Control. Usually not required.

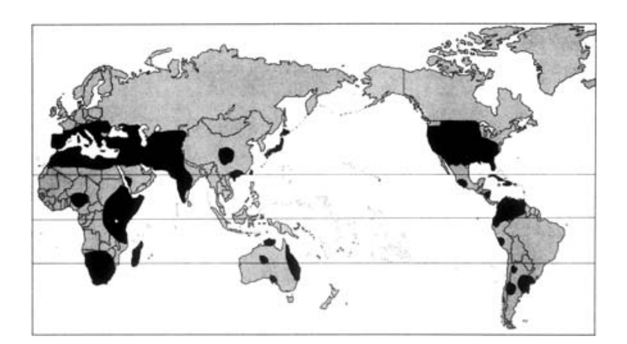
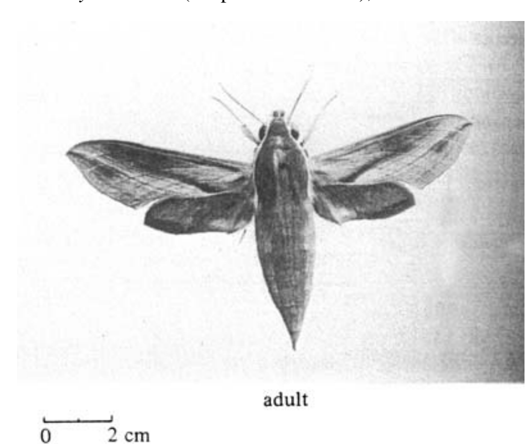


Fig. 9.305. Hyles lineata (Striped Hawk Moth); S. China.



Manduca spp.

(*M. quinquemaculata* (Haw.))
(*M. sexta* (L.))

Common name. Tomato Hornworm; Tobacco Hornworm
Family. Sphingidae
Hosts (main). Tomato and tobacco; also potato.
(alternative). Other Solanaceae, both crops and wild plants.
Damage. The large larvae eat the leaves of the host plant and frequently cause defoliation; then the plant usually dies.
Pest status. Serious pests of solanaceous crops in the New World, due entirely to their voracious leaf-eating, which leads to defoliation, and their rapid development.
Life history. Eggs are laid singly or in small groups on the underside of leaves; they are spherical in shape, green in colour; hatching takes about five days.

The caterpillars differ somewhat in appearance; *M. sexta* is yellowish-green with seven lateral white, oblique lines, and the horn is curved and red; *M. quinquemaculata* has seven or eight lateral white stripes connected below the spiracles (giving a series of curved shapes), with the horn straight and black; brown larvae are sometimes seen. Fully grown larvae are 9–10 cm. Larval development through five instars takes only 3–4 weeks in southern USA. Pupation takes place in the soil and requires 2–4 weeks.

The adults are grey with fine black markings, and a series of yellow patches along the abdomen; wingspan is 10–12 cm. Like most of the Sphingidae they are nocturnal and take nectar from flowers at night.

Depending upon latitude, there are 1–4 generations annually.
Distribution. These two species are broadly sympatric, although they differ in abundance relatively, over an area from southern Canada (Ontario), through the USA into S. America.

Several other species of *Manduca* are known and a couple of them are also recorded as larvae feeding on Solanaceae.

In the Old World their niche is occupied by *Acherontia* (page 449).
Control. Various natural enemies are of importance in the USA, particularly the larval parasite *Apanteles congregatus* (Say). Deep ploughing will usually destroy many of the pupae in the soil.

In gardens hand-picking is recommended, but for commercial crops it is often necessary to use insecticides, although it must be noted that the large larvae are extremely difficult to kill with poisons. Spray timing is aimed at the young larvae, using carbaryl, endosulfan, parathion, toxaphene, also BTH and several other compounds.

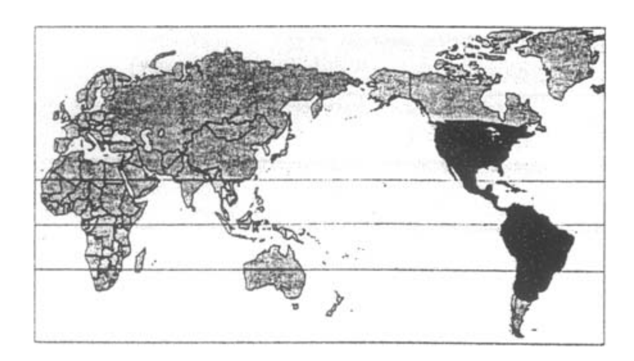
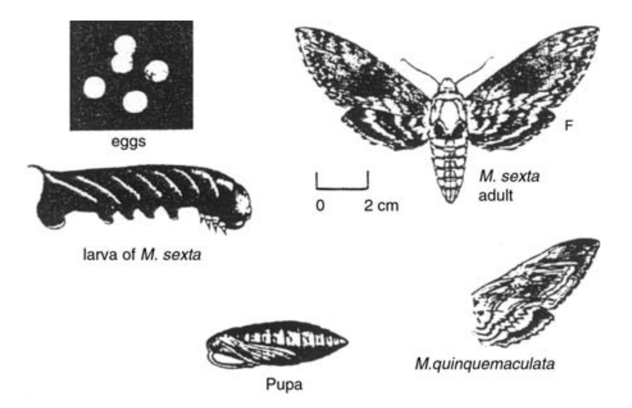


Fig. 9.306. Manduca spp. (Tomato/Tobacco Hornworm); USA.



Agrotis ipsilon (Hfn.)
(= *Euxoa ypsilon* Rott.)
(= *Scotia ipsilon* Rott.)

Common name. Black (Greasy) Cutworm
Family. Noctuidae
Hosts. A polyphagous cutworm attacking the seedlings of most crops, in particular cotton, rice, potato, tobacco, cereals, and crucifers.
Damage. The young larvae feed on the leaves of many crops; the older caterpillars feed at the base of crop plants or on the roots or stems underground. Seedlings are typically cut through at ground level; one caterpillar may destroy a number of seedlings in this manner in a single night.
Pest status. A cosmopolitan pest of sporadic importance on many crops in different parts of the world. It can cause severe damage on rice in S.E. Asia and in Australasia. On other crops the occasional severe infestation usually results in devastating damage.
Life history. The eggs are white, globular, and ribbed; 0.5 mm in diameter; and hatch in 2–9 days. Each female may lay as many as 1800 eggs.

The larvae are brownish above with a broad pale grey band along the mid-line, and with grey-green sides with lateral blackish stripes. The head capsule is brownish-black with two white spots. The general appearance of the caterpillar is blackish. The mature caterpillar is 25–35 mm long; larval development takes 28–34 days. In temperate countries some larvae overwinter as such, and pupate in the late spring. The first two instars feed on the foliage of the plant, the third instar becoming non-gregarious, in fact often cannibalistic, and adopting cutworm habits.

The pupa is dark brown, 20 mm long, with a posterior spine; pupation takes 10–30 days, according to temperature.

The adults are large, dark noctuids with wingspan of 40–50 mm, with a grey body, grey forewings with dark brownish-black markings; the hindwings are almost white basally but with a dark terminal fringe; paler in the males.

The life-cycle from egg to adult takes 32 days at 30°C, 41 days at 26°C, and 67 days at 20°C.
Distribution. Almost completely cosmopolitan, from northern Europe, Canada, Japan, down to New Zealand, S. Africa, and S. America. It has not been recorded to date from a few areas in the tropics (e.g. S. India, N.E. South America) (CIE map no. A261).
Control. See following section on the control of cutworms.

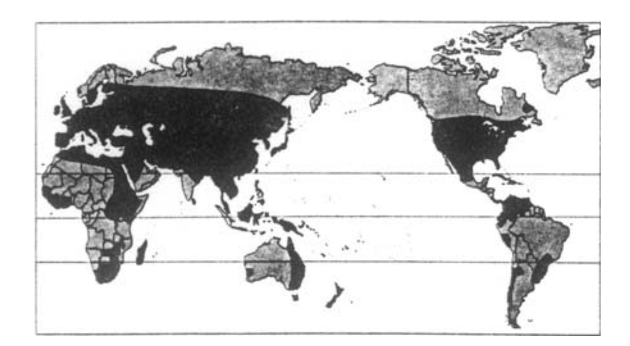
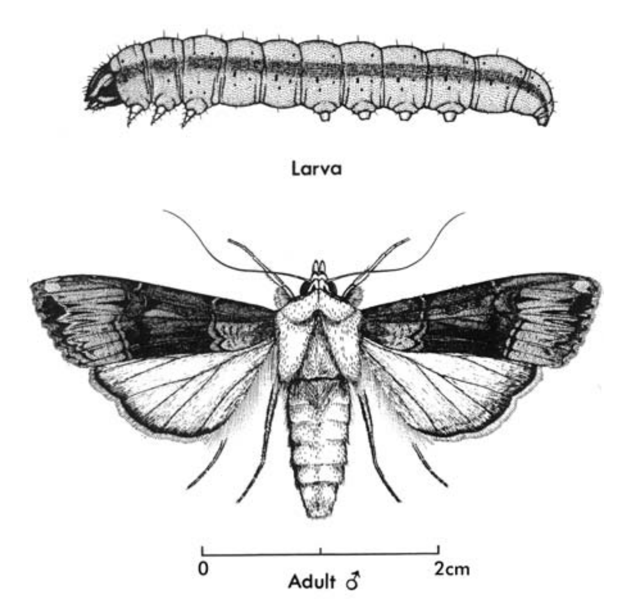


Fig. 9.307. Agrotis ipsilon (Black Cutworm); Cambridge.



Control of Cutworms (Lepidoptera; Noctuidae)

Cutworms are the caterpillars of various Noctuidae, belonging mostly to the genera *Agrotis* and *Euxoa*; the group (and some species) is completely cosmopolitan in distribution. They are generally more important in temperate rather than tropical situations. (The genera *Agrotis* and *Euxoa* are very closely related and separated only by minor esoteric taxonomic characters, and some species have been placed in both genera at different times.)

The larvae are nocturnal in habits and spend the day hiding in the litter or in the soil sometimes to a depth of up to 10 cm. Whilst subterranean they will feed on plant roots and tubers, boring a wide shallow hole (somewhat like slug damage) in potatoes (see p. 76) and other root crops. Thick-stemmed vegetables, such as lettuce and brassicas may have the stem below ground completely hollowed out; the attacked plant first wilts and then dies. At night the larvae customarily come to the soil surface and feed on plant stems at about ground level. Damage to seedlings and close-planted crops (carrots, lettuce, celery, red beet, some brassicas) is particularly serious, and root crops such as potato, turnip and parsnip are often severely damaged. Typical damage is for the cutworm to move along the row of seedlings cutting each one through the stem at ground level. Root damage is generally most serious in light soils where the soft-bodied caterpillars can burrow more easily.

The female moths lay many eggs (1000–3000), in a series of batches, usually on leaves and stems of weeds or crop plants, or sometimes on litter or plant debris. The first instar larvae feed on the leaves of the host plants, and when larger they descend to the soil and adopt typical cutworm habits. There are typically six (sometimes five) larval instars.

Some species are migratory, and most are characterized by extreme population fluctuations, being abundant in some years and scarce in others.

Suggested control methods of population control are as follows.

(1) Cultural methods
- (a) Weed destruction – these plants are often preferred sites for oviposition, and food for the first instar larvae.
- (b) Hand-collection of larvae – often more suitable for gardens and small-holdings
- (c) Flooding of the infested field may be feasible for some crops.
- (d) Deep ploughing will bring larvae and pupae to soil surface for exposure to predators and sun.

(2) Chemical methods
- (a) High-volume sprays (at least 1000 l/ha) of insecticides.

DDT (25%)	4.2 l/ha
endrin (w.p.)	3.75 l/ha
chlorpyrifos (48% e.c.)	2.5 l/ha
triazophos (40% e.c.)	2 l/ha
cypermethrin, fenitrothion	75g a.i./ha

The spray should be directed along the plant rows, aiming at run-off to the soil below.

Timing should ideally be aimed at the young caterpillars whilst still feeding on the plant leaves or on the soil surface.

- (b) Soil application of bromophos (w.p.) or chlorpyrifos granules.
- (c) Baits of moist bran mixed with DDT, γ-BHC or endrin may be effective against older caterpillars; Sodium fluosilicate in Israel.

Generally cutworms are extremely difficult to control, especially in 'boom' years, for by the time infestations are apparent the susceptible stages of the larvae are often past, and damage may be already quite serious. The sporadic nature of cutworm population outbreaks makes preventative treatments rather futile in most areas. Finally the soil-dwelling larvae often under dense and continuous crop foliage, make targets difficult to 'hit' with insecticides, and in many areas such high-volume spraying is not feasible because of water shortages and equipment restrictions.

Agrotis segetum (D. & S.)
(= *Euxoa segetum* Schiff.)

Common name. Common Cutworm (Turnip Moth)
Family. Noctuidae
Hosts. A polyphagous cutworm attacking the seedlings of many crops, and many vegetables and root crops.
Damage. Seedlings are cut through the stems just above ground level; one caterpillar may cut through a number of seedlings in one night. Root crops may be deeply gnawed, often at levels well below the soil surface. The bark of young coffee trees may be scarred.
Pest status. A cosmopolitan pest of sporadic importance on a wide range of crops; occasionally the damage by this pest may be devastating.
Life history. The eggs are laid on the stems of weeds or crop plants, or on the soil, and they hatch in 10–14 days. Each female may lay up to 1000 eggs.

The early instars generally remain on the foliage of the host plants for a week or two, then as the caterpillars develop they gradually move down into the soil and assume the cutworm habits. They usually remain in the soil during the day and come to the surface to feed at night. Sometimes the older caterpillars may remain in the soil all the time feeding on the roots of carrots, other root crops and potatoes. The clay-coloured caterpillar is about 30–40 mm long at maturity with faint dark lines along the sides of the body.

The pupa is smooth shiny brown with two spines at the rear; 20–22 mm long. Pupation takes place in the soil.

The adult moth is 30–40 mm across the wings; the forewing is grey-brown with a dark brown or black kidney-shaped marking; the hindwings are almost white in the male, but darker in the female.

There is only one generation per year in Europe but there may be four per year in Africa.
Distribution. Cosmopolitan, with the exception of the American continent; occurring in all of Africa, Europe, USSR, the Asian mainland, Sri Lanka, Taiwan, Japan, and Indonesia.
Control. As for *A. ipsilon*.

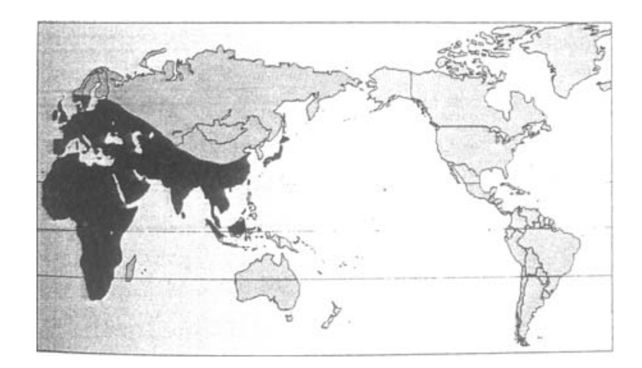
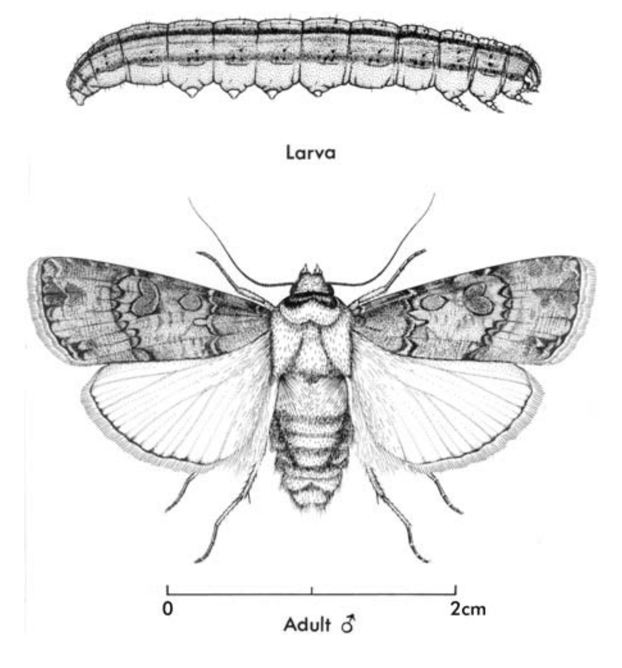


Fig. 9.308. Agrotis segetum (Common Cutworm); Cambridge, U.K.



Busseola fusca (Fuller)

Common name. Maize Stalk Borer
Family. Noctuidae
Hosts (main). Maize and sorghum.

(alternative). Young caterpillars can be found in many species of grass and cereals, but only those with thick stems can support the larvae to maturity.

Damage. Young plants have holes and 'windows' in the leaves, and small dark caterpillars may be seen in the funnel. In severe attacks the central leaves die. In older plants the first generation caterpillars bore in the main stem and later some of the second generation caterpillars may be found boring in the cobs.

Pest status. A major pest of maize and sorghum in E. Africa and other parts of tropical Africa, in areas with an altitude greater than about 700 m.

Life history. The globular eggs are about 1 mm in diameter, and are laid under a leaf sheath in a long column stretching up the stem. They are white when first laid but darken with age. 400 eggs laid in batches of up to 150. Hatching takes place after about ten days.

The larva is a buff or pinkish caterpillar with more or less distinct black spots along the body; and the full-grown size is about 40 mm long. On hatching the first instar larvae are blackish; they crawl up the plant into the funnel where they eat the leaf tissues, leaving only the epidermal layer on the supper surface (i.e. 'windows'). After some time they either move to another plant or bore down the funnel into the centre of the stalk where they feed until fully grown. The mature caterpillar cuts a hole in the side of the stem before pupating within the tunnel. The total larval period is usually 35 days or more. There are usually two generations of Stalk Borer before the crop ripens. In the second generation some eggs may be laid on the cobs, where the caterpillars also feed but move into the stem when fully grown. The mature caterpillar of the second generation often goes into a diapause which will be broken at the onset of the next rainy season when it will prepare a pupal chamber in the stem and pupate.

The pupa is brown and about 2.5 mm long; the pupal stage lasting ten days or more, according to temperature.

The adult is a brown night-flying moth with a wing-span of about 35 mm. It emerges through the hole in the stem prepared by the mature caterpillar. There is a pre-oviposition period of 2–3 days.

Distribution. A widespread pest in the maize-growing areas of tropical and subtropical Africa, from S. of the Sahara down to S. Africa.

Control. See following section on the control of cereal stalk borers.

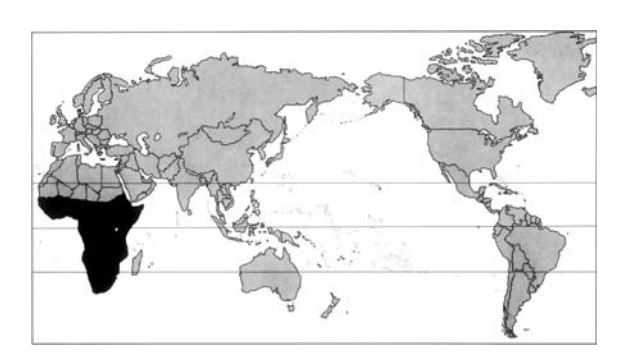


Fig. 9.309. Busseola fusca (Maize Stalk Borer); Kenya.



Control of Cereal Stalk Borers (Pyralidae & Noctuidae)

As with the other borers (except fruit flies) the eggs are laid on the plant foliage and the young larvae have to find their way to the stem. But these caterpillars are slightly different from other borers in that the first instars usually feed on the leaves for a while before entering the stem (see illustration of feeding damage on page 67). The site of oviposition is usually under the leaf sheath. The young larvae are thus vulnerable to contact insecticides while they are feeding inside the funnel of the cereal seedling.

Experience has shown that cereal stem borers are often best attacked by an IPM programme, as demonstrated by the successes on sugarcane in the USA (Hensley, 1980), and maize in New Zealand. The different ways in which stalk borers can be controlled are enumerated below.

(1) Cultural control
- (a) Resistant varieties – some varieties with tight or extensive leaf sheaths are not favoured for oviposition; other varieties have an increased silica content in their tissues and feeding larvae usually die.
- (b) Simultaneous sowings over a large area prevent population build-up.
- (c) Destruction of crop residues – important for killing of pupae left in old stems and tall stubble.
- (d) Destruction of thick-stemmed grass weeds which would act as alternative hosts.
- (e) Close season of at least two months to prevent population continuity.

(2) Biological control
- (a) *Trichogramma* spp. (Chalcidoidea) as egg parasites.
- (b) *Apanteles* spp. (Braconidae) as larval parasites.

(3) Insecticidal control
- (a) Dusts Contact insecticides applied down the funnel of young plants to kill the emerging and feeding first instar larvae.
- (b) Sprays
- (c) Granules – applied either by foliar lodging, to the soil, or to the water for paddy rice; usually systemic in action.
- (d) Systemics applied as sprays.

  The list of effective chemicals being used against cereal stalk borers is extensive, and includes DDT, γ-BHC, endrin, azinphos-methyl, diazinon, endosulfan, fenthion, fenitrothion, monocrotophos, phorate, phosphamidon, tetrachlorvinphos, triazophos, carbaryl and carbofuran, either as powders, sprays or granules.

Resistance is a problem in some areas, and also certain species are less sensitive to some chemicals, so that local advice should be sought for control of any particular stalk borer.

Diparopsis spp.
castanea (Hamps.)
watersi (Roths.)

Common name. Red Bollworms (Red Bollworm; Sudan Bollworm)
Family. Noctuidae
Hosts (main). Cotton

(alternative). This pest is oligophagous (almost monophagous) in being restricted to *Gossypium* and the two closely related genera *Cienfuegosia* and *Gossypioides*, although odd records from other Malvaceae have been made.

Damage. The young larvae bore into flower buds which are then eaten out and later dehisce. Usually a few buds are eaten before the larva penetrates a boll and remains inside eating out the contents.

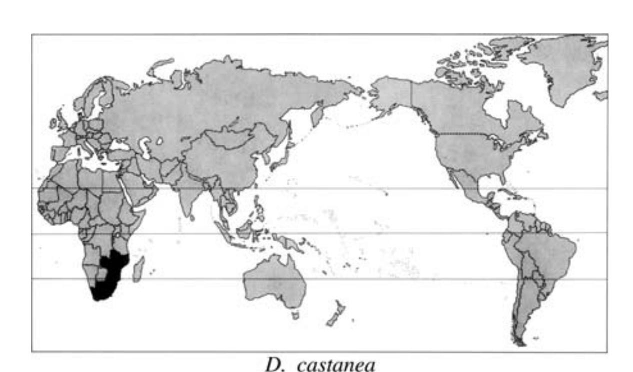
Pest status. These species are major pests of cotton in Africa; *D. castanea* being found S. of the Equator, and *D. watersi* N. of the Equator. There are two other species of *Diparopsis* attacking cotton in Africa.

Life history. The eggs are subspherical, 0.5–0.7 mm in diameter, bluish in colour, with both vertical and horizontal ribbing; usually laid singly on young leaves or stems, taking 4–10 days to hatch. Each female may lay up to 500 eggs.

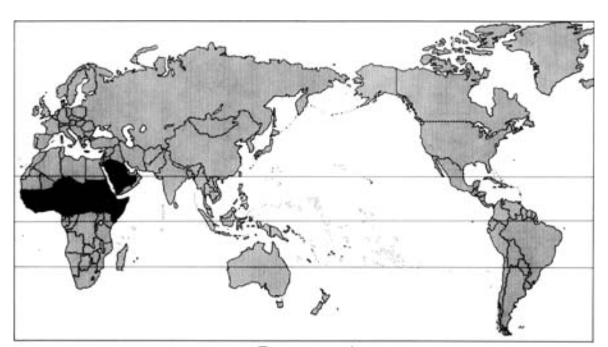
The newly hatched larva is pale, with head, prothoracic plate, anal plate, and legs black. The characteristic red markings appear in the second instar, and consist of a median dorsal mark flanked with an oblique one on either side, and with a broad lateral mark above each spiracle. The mature larva is 25–30 mm long. Larval development takes 11–23 days. The young larvae soon start boring into buds and young bolls; each larva may consume six or more flower buds, or alternatively it may spend most of its life within one cotton boll.

Pupation takes place in an earthen cell in the soil at depths of up to 15 cm, and lasts some 2–3 weeks, unless diapause is involved when the period of quiescence may be as long as 35 weeks.

The adult moths are stout-bodied with wingspan of about 25–35 mm. The abdomen and hind-wings are silvery cream, the latter slightly infuscate at the margins which are fringed. The forewing colour is quite variable but the commonest pattern is with the central area reddish, basal and distal bands a shade darker, and the penultimate band grey-brown. However, both yellowish and greenish-pink forms occur. The two species are difficult to separate on the grounds of forewing coloration.

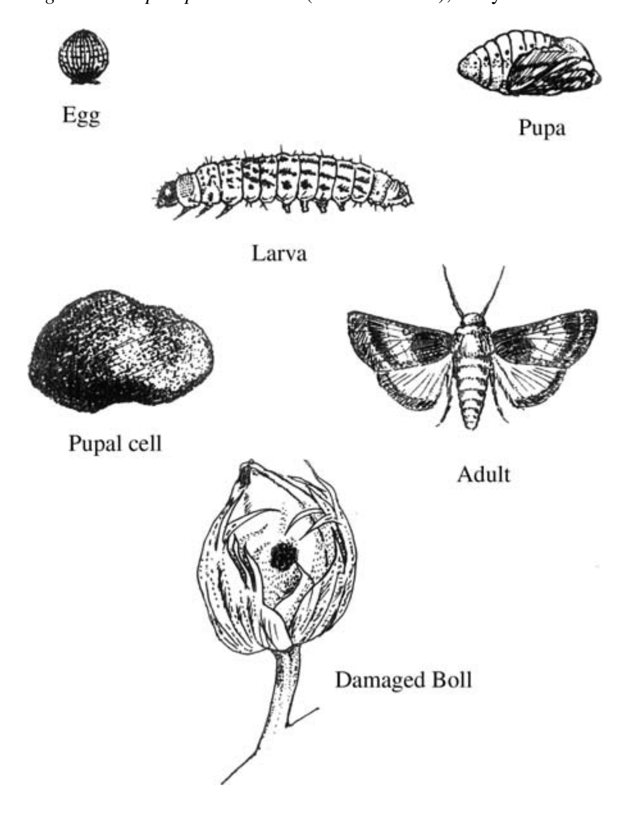


D. castanea



D. watersi

Fig. 9.310. Diparopsis castanea (Red Bollworm); Kenya.



The moths are sexually mature upon emergence, and mating and oviposition may occur on the night of emergence.
Distribution. *D. castanea* occurs in S.E. Africa, in the Transvaal, Natal, Swaziland, Mozambique, Zimbabwe, Malawi, and Zambia.

D. watersi is found in the Sudan, and from Somalia across to Senegal, all areas being north of the Equator in Africa (including Sierra Leone, Guinea, Ivory Coast, Ghana, Upper Volta, Mali, Benin, Nigeria, Cameroons, Chad, Central African Republic and Ethiopia). It is also found in Arabia.

This genus does not occur in E. Africa or Zaïre, except for records in the southernmost tip of Tanzania.
Control. Control in E. Africa is by legislative means through the maintenance of a cotton-free zone in S. Tanzania, which has to date effectively prevented the spread of this pest from Zambia and Malawi into E. Africa.

The recommended insecticides for the control of Red Bollworm are sprays of carbaryl applied weekly, starting when the first flower buds appear, the results generally improving as the number of sprays is increased from four to eight.

DDT, BHC/DDT, DDT/toxaphene, ethion, and monocrotophos were also recommended by Wyniger (1968).

Control of Bollworms on Cotton
The caterpillars that bore developing cotton bolls belong to several different families (i.e. Gelechiidae, Tortricidae), but most are Noctuidae. Eggs are laid on the young foliage (terminal shoots, leaves and squares) and the first instar larvae have to search for the young bolls or buds. A single larva may destroy several buds or may spend its entire larval period inside a single boll. As with other borers once the larva is inside the boll it is safe from contact insecticides, and generally it is not worthwhile trying to control bollworms with systemics, for once the larva is in situ the developing lint is already damaged. Thus, when using contact insecticides, the timing of application is absolutely vital for control of cotton bollworms.

Scouting for eggs in the crop, or field-sampling of foliage for eggs, is generally recommended twice weekly at the appropriate time, and insecticide sprays applied when the first eggs are found. Sprays should be applied to the crop foliage at weekly intervals so long as the egg-laying period persists. The first eggs are generally found at the time of the first flower buds, which is some six weeks after germination.

The insecticides used at present are mainly carbaryl, cypermethrin and endosulfan, but for American Bollworm usually endosulfan is recommended, as carbaryl was only reported effective against it in areas of low rainfall. For mixed bollworm infestations, a spray mixture is generally advised although cypermethrin is reported to be effective. For Pink Bollworm control is aimed at killing adults, to the eggs are laid on the young bolls and the larvae bore directly into the bolls.

Earias spp.
biplaga Wlk.
insulana (Boisd.)
vittella (F.) (= *E. fabia* Stoll)

Common name. Spiny Bollworms
Family. Noctuidae
Hosts (main). Cotton, okra.

(alternative). Species of *Hibiscus* and *Abutilon* and other Malvaceae; also cocoa and a few members of the Tiliaceae and Sterculiaceae.

Damage. Terminal shoots of young cotton plants are bored, causing death of the tip and subsequent development of side-shoots and branches. Flower buds and young bolls are shed after being bored by the caterpillars; large bolls are bored but are not shed.

Pest status. Present in many Old World cotton-growing areas most seasons and sometimes very severe attacks occur.

A total of seven species of *Earias* are found on cotton in different parts of the Old World.

Life history. The eggs are blue, subspherical, about 0.5 mm in diameter; the shell is ribbed and alternate ribs project above the egg forming a crown. Eggs of *E. insulana* have longer projections than those of *E. biplaga*. Oviposition occurs anywhere on the plant; on young plants they are usually found singly on young shoots; on older plants they are usually on the stalks or bracteoles of flower buds or young bolls. Hatching takes 3–4 days.

The larva is a stout, spindle-shaped caterpillar which, when fully grown, is 15–18 mm long. Most segments have two pairs of fleshy, finger-like tubercles which give the caterpillar its common name. The colour is variable but is usually pale brown tinged with green or grey and with yellowish spots. *E. insulana* larvae are usually paler in colour than *E. biplaga*. There are five larval instars, the larval period taking 12–18 days. In young plants the caterpillars bore in the soft terminal shoots causing death of the growing point. Older larvae feed on flower buds (squares) and green bolls of various ages. The bracteoles of damaged flower buds open out, causing the condition known as ‘flared squares’. The entrance hole of the caterpillar in a bud or boll is neat and circular and may be blocked with frass.

The mature caterpillar spins its cocoon on the plant or among the plant debris on the soil surface and pupates inside it. The pupa is brown with rounded ends and is about 13 mm long; the pupal stage lasts 7–12 days.

The adult *E. insulana* is a small moth with green or yellowish-green wings, pale hindwings, and a wing-span of 20–22 mm. The adult *E. biplaga* male usually has yellow forewings with a brown edge and brown markings. The female has greenish forewings which have a brown edge and a brown patch in the centre of the wing.

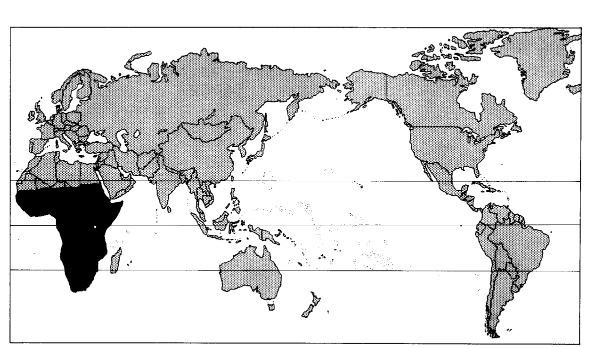
After a pre-oviposition period of 3–4 days the female moth may live a further 40 days, and lay 300–600 eggs.

Distribution. The genus *Earias* is confined to the Old World including Australasia; *E. insulana* covers most of Africa, to the Mediterranean and S. Europe, Middle East, to India and S.E. Asia including the Philippines (CIE map no. A251).

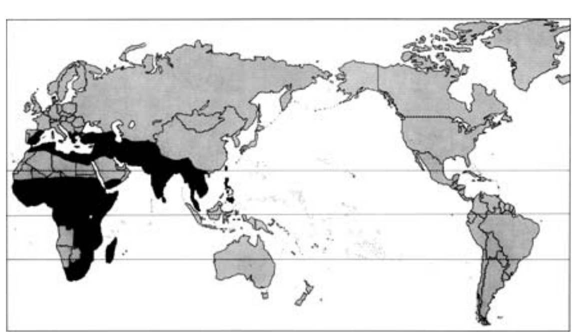
E. biplaga is confined to Africa south of the Sahara.

E. vittella is the common Oriental species, found from India and China to N. Australia (CIE map no. A282).

Control. To control Spiny Bollworms effectively it is necessary to apply the sprays while the caterpillars are still small. The recommended insecticides were carbaryl and a mixture of DDT + BHC dusts, endosulfan a several pyrethroids are currently being used.



E. biplaga



E. insulana

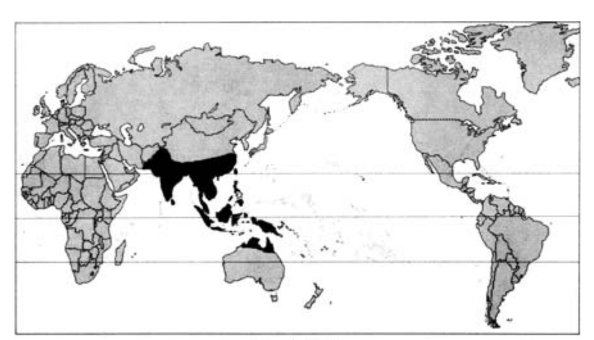
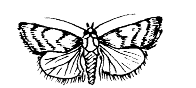
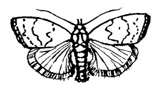
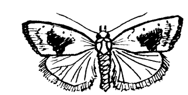
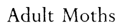

E. vittella

Fig. 9.311. Earias spp. (Spiny. Bollworms); Kenya.

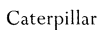


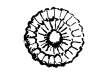


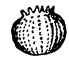






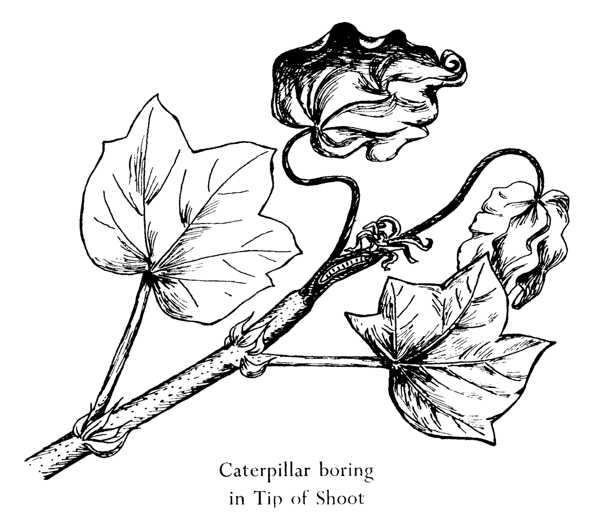












Helicoverpa armigera Hb.
(= *Heliothis obsoleta*)
(= *Heliothis armigera* Hb.)

Common name. Old World Bollworm
Family. Noctuidae
Hosts (main). Cotton, beans, maize and sorghum.
(alternative). Tobacco, tomato, many legumes, some vegetables, and other plants.
Damage. Clean circular holes are bored in flower buds, cotton bolls of all sizes and some fruits.
Pest status. A sporadically very serious pest of cotton and beans in many parts of the Old World; completely polyphagous, and a minor pest on many cultivated fruits (in the botanical sense).
Life history. Eggs are spherical, 0.5 mm in diameter, yellow turning brown; hatching takes 2–4 days. Each female moth may lay 2000 or more eggs (14,000 recorded).

The larva is stout, greenish or brown, but variable in coloration. Body bears long dark and pale bands; fully grown larvae are 40 mm long. There are six larval instars and the total period lasts 14–24 days, but 51 days at 17°C.

Pupation takes place in the soil; the shiny brown pupa is about 16 mm long; pupal development takes 10–14 days in the tropics, but there may be pupal diapause. The adult is a stout-bodied, brown nocturnal moth of wingspan about 40 mm.

The complete life-cycle can be as short as about 28 days in the tropics, and there are several generations (3–5) each season; in Europe there are probably only two generations per year, the second over-wintering as pupae in diapause. In the tropics 10–11 generations have been recorded.
Distribution. Widespread throughout the tropics, subtropics and warmer temperate regions of the Old World, extending as far north as Germany and Japan (CIE map no. A15). *Heliothis* spp. (80+) are worldwide on a very wide range of crops, mostly as minor pests.
Control. Maize during the tasselling period, and flowering legumes, are attractive to this species and will divert egg-laying females from the cotton; little damage is done to the maize and beans because of the high larval mortality on these crops.

For chemical control, apply insecticides when caterpillars are small; the usual insecticides have been DDT, BHC (or a mixture of the two), endosulfan, carbaryl and now the polyhedral virus is available. Resistance to these chemicals is widespread and pyrethroid alternative are being used. Larger caterpillars are typically very difficult to kill with insecticides.

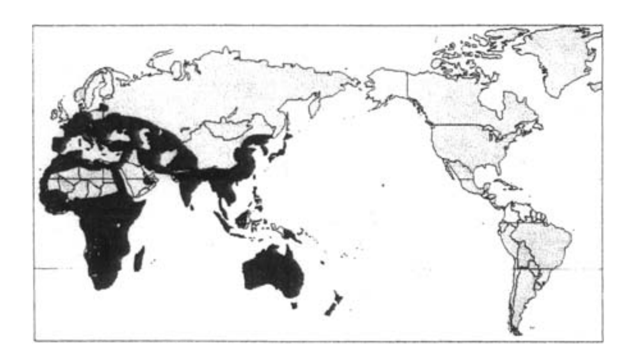
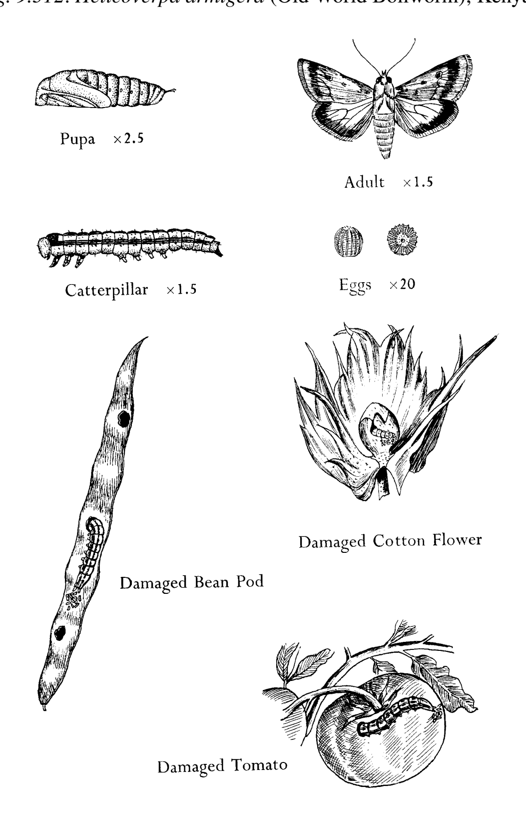


Fig. 9.312. Helicoverpa armigera (Old World Bollworm); Kenya.



Helicoverpa zea (Boddie)

Common name. Cotton Bollworm; Corn Earworm; Tomato Fruitworm; American Bollworm.
Family. Noctuidae
Hosts (main). Cotton, maize, beans, tobacco, tomato.

(alternative). Okra, sorghum, cabbage, other legumes, cucurbits, sunflower, capsicums, strawberry, Pea, clovers and many other crops and wild hosts.

Damage. Caterpillars generally feed on the fruiting points of the host; on maize they eat the tassels and the young soft grains at the top of the cob. Often secondary rots develop in the insect feeding sites.

Pest status. A major pest in the New World, especially on maize cotton, because of its polyphagous feeding habits, wide distribution and large size of the larvae.

Life history. The spherical eggs are laid singly, stuck to the plant, and one female has been recorded laying as many as 3000 eggs.

Larvae are variable in colour and have several alternating pale and dark lines along the body and after 5 to 7 instars they attain a length of 40–45 mm. Larval development takes from 28–60 days.

Pupation takes place in the soil, as with most Noctuidae, and the dark brown pupa measures about 20 mm; there may be pupal diapause.

The adults are brown moths with a pale hindwing bordered by a dark band, about 40–44 mm in wingspan.

There are usually 3–5 generations per year, according to location, but 10–11 are possible in the tropics.

Distribution. The New World from Canada down to Argentina, including the W. Indies, and also Hawaii (CIE map no. A239). This species is virtually indistinguishable from *H. armigera*

Control. Various aspects of cultural control are practised against this pest, including the use of resistant varieties of crop plants, destruction of crop residues, uniform and early planting.

Natural control is important in many areas.

For chemical control see *H. armigera*.

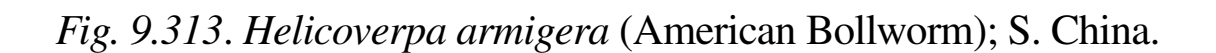
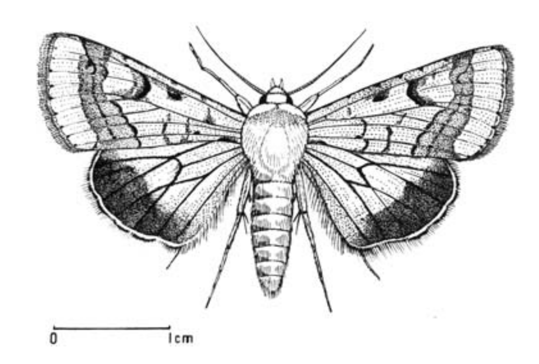


Fig. 9.313. Helicoverpa armigera (American Bollworm); S. China.

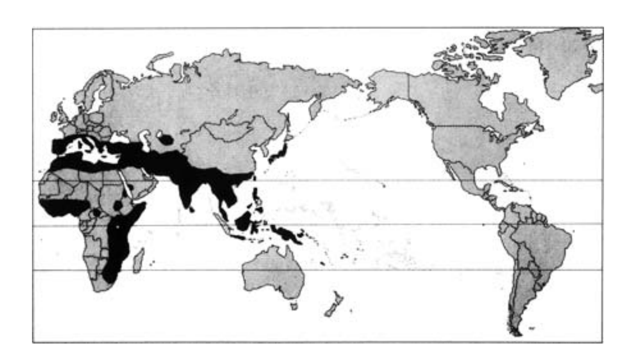




mature larva on cabbage heart

Mythimna loreyi (Dup.)
(= *Cirphis loreyi* (Dup.))
(= *Leucania loreyi* (Dup.))

Common name. Rice (Cereal) Armyworm
Family. Noctuidae
Hosts (main). Maize, rice.
(alternative). Sugarcane, sorghum, wheat, etc.; essentially polyphagous on Gramineae.
Damage. Leaves are skeletonized by young larvae, and later the older caterpillars become gregarious and feed voraciously, eating entire leaves and sometimes the whole plant, usually during the night.
Pest status. An important pest on a number of different graminaceous crops; sporadically serious, when entire crops may be destroyed.



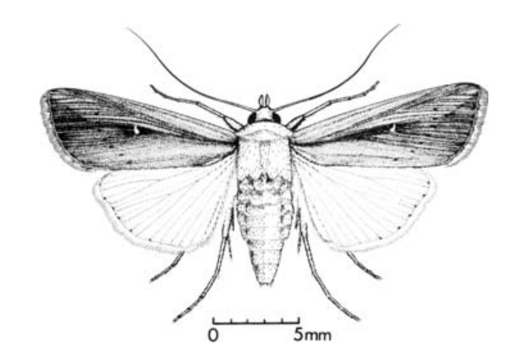
Life history. Eggs are laid in batches of up to 100 between the leaf sheath and the stem, and hatch in about five days.

The caterpillars are quite variable in colour, but usually have several distinctive longitudinal stripes. There are usually six larval instars, and the larger caterpillars are generally gregarious. Mature size is some 35–40 mm.

Life history details are probably similar to those of *M. separata*. The adult moth is pale brown, with a small spot in the middle of the forewings and whitish hindwings; wingspan is from 35–50 mm.

There are usually several generations per year.
Distribution. Recorded from the Mediterranean region, W. and E. Africa, Middle East, India through to China and Japan, extending down to Papua New Guinea (CIE map no. A275); a closely related but different species occurs in Australia.
Control. See under *M. unipuncta*.

Fig. 9.314. Mythimna loreyi (Rice Armyworm); Kenya.



Mythimna separata (Wlk.)
(= *Leucania separata* Wlk.)
(= *Pseudaletia separata* (Wlk.))

Common name. Oriental Armyworm
Family. Noctuidae
Hosts (main). Rice
(alternative). Sugarcane, sorghum, maize, millets, wheat, oats, barley, rye, legumes, *Brassica*, tobacco and various wild grasses and sedges.
Damage. The young larvae eat the leaves of the host plant, and generally defoliate, but the sixth instar caterpillars may also climb the peduncle and cut off the rice panicles. Large caterpillars are often gregarious and may occur in vast numbers.
Pest status. A serious pest of rice throughout S.E. Asia, and also on some other crops, especially when the larvae aggregate in large numbers, when their nocturnal feeding activities may completely defoliate crops.
Life history. Eggs are laid in batches of about 100 inside the rolled leaves or between the leaf sheath and stem; they are subspherical (about 0.5 mm), greenish-white turning yellow, and take about five days (4–13) to hatch.

Larvae are variable in colour, from green to pinkish, but have four longitudinal black stripes laterally, with a white mid-dorsal stripe in young stages, darkening later. Mature length is 35–40 mm. There are six larval instars usually, and the last instar larva eats about 80% of the total food consumed as a larva; large caterpillars are voracious in appetite. Larval development takes about 18 days (14–22); large larvae are usually gregarious, occasionally vast swarms of larvae are found and crop defoliation may be widespread.

The pupa is dark brown, 15–19 mm long, and is formed in an oval cocoon about 4 cm deep in the soil; pupation takes about 18 days (7–29).

Adult moths are brownish in colour with some faint marks on the forewings; wingspan is from 35–50 mm. Males live for about three days and females for about seven; both sexes may feed on honey-dew excreted by various Homoptera.

The life-cycle takes about 30 days in the tropics, but varies from 25–64 days; there are often five generations per year.
Distribution. Pakistan, India, S.E. Asia, Papua New Guinea, West Irian, Australia (Queensland), New Zealand, China, Korea, and Japan (CIE map no. A230).
Control. See *M. unipuncta*.

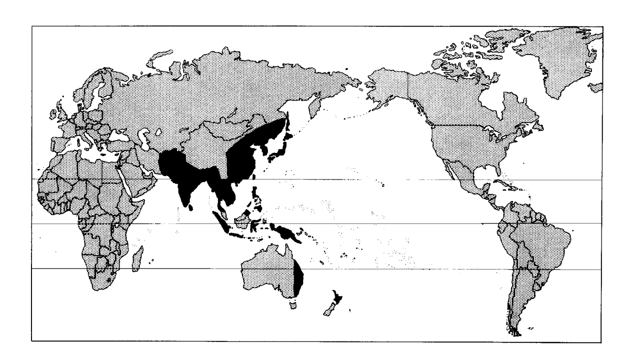
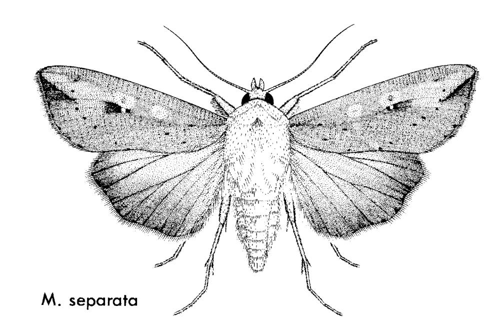


Fig. 9.315. Mythimna separata (Oriental Armyworm); S. China.



Mythimna unipuncta (Haw.)

(= *Cirphis, Leucania* & *Pseudaletia unipuncta* (Haw.))

Common name. Rice Armyworm (American Armyworm)
Family. Noctuidae
Hosts (main). Rice

(alternative). Other cereals and forage crops, including maize, sugarcane, flax, wheat, rye, barley, oats, buckwheat and Jerusalem artichoke.

Damage. Defoliation by the feeding larvae; when gregarious swarms occur then complete crop destruction may follow.
Pest status. A sporadic pest, but occasionally serious, especially so when swarming occurs.
Life history. Very similar to *M. separata* in all stages, both morphologically and in life history details. Identification usually requires a taxonomic expert.

A series of closely related species are to be found on rice and other crops throughout the warmer parts of the world, but their identification is difficult.

Distribution. S. Europe, Mediterranean region, W. Africa, Somalia, Iran, Israel, USSR, USA, Hawaii, C. and S. America (CIE map no. A231).
Control. For all the species of *Mythimna* cultural methods such as ploughing or burning of stubble, flooding infested fields, removal of grass and alternative hosts from around the fields, all help to reduce the pest populations.

Some species are regularly parasitized by braconid wasps, ichneumons, and Tachinidae, in the larval stages, which are also susceptible to polyhedrosis virus and *Bacillus thuringiensis*.

As with other sporadic pests, chemical control is difficult to time because the pest population is usually large by the time it is noticed. Dust and spray with contact insecticides such as DDT, BHC, endrin, parathion, dichlorvos, trichlorphon or fenitrothion. In some areas the use of the organochlorine compounds is no longer approved, but the latter chemicals should prove effective.

Baits are sometimes used against the swarming caterpillars.

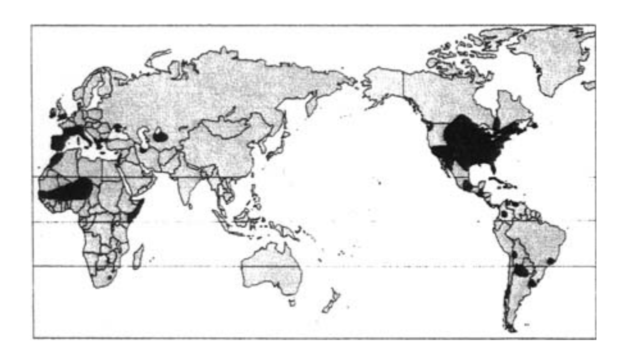
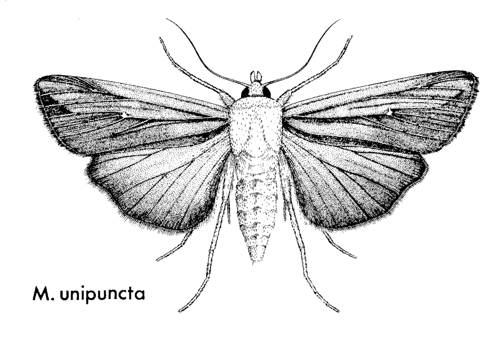


Fig. 9.316. Mythimna unipuncta (Rice/American Armyworm); Kenya.



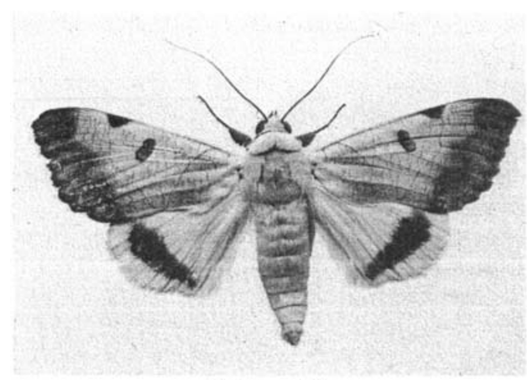
Othreis fullonia (Cl.) etc.
(= *Ophideres fullonica* L.)

Common name. Fruit-piercing Moths
Family. Noctuidae
Hosts (main). *Citrus*, (mango, papaya, guava.)
(alternative). Banana, tomato, grapes, and some wild fruits.
Damage. The adult moths pierce the ripening fruits to obtain sap. The proboscis is short and stout with a barbed tip. The damaged fruits usually develop secondary rots and fall prematurely.
Pest status. Only occasionally do fruit-piercing moths cause any appreciable damage, then it is usually *Achaea* spp. in parts of W. Africa; *O. fullonia* is more of academic interest than economic.
Life history. No details are available.

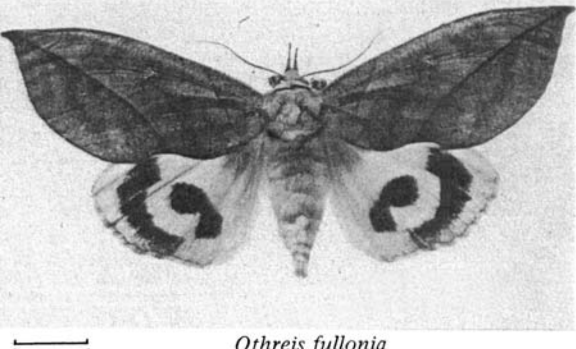
There are several genera of Noctuidae involved as fruit-piercing moths, including *Achaea* (Africa and India), *Serrodes, Anomis*, and, in S.E. Asia, *Calpe, Othreis* and *Ophiusa* spp.; there are also a few other less well-known genera. The larvae of *Achaea* spp. are defoliators of castor plants, and one species in India is known as the Caster Semi-looper. Larvae recorded on *Tiliacora* in Java, and *Anamirta* in Indonesia, and grow to a length of 85 mm.
The life cycle takes 28–39 days in Java.

Two species from S.E. Asia are illustrated here: *O. fullonia* has brown, leaf-like forewings and bright yellow hindwings – it has a very stout proboscis and apparently feeds mostly on *Citrus; Ophiusa tirhaca* has forewings which are basically greenish with brown markings, and yellow hindwings with a dark band – its proboscis is less stout and it feeds on softer fruit.
Distribution. *Othreis fullonia* is recorded from parts of Africa, through India, S.E. Asia up to China, Korea and Japan, and through the Philippines to Papua New Guinea and N.E. Australia (CIE map no. A377).
Control. Fortunately, control is seldom required, for it would be most difficult, partly because the larvae do not develop in the crops that are attacked by the adults, and partly because of the nature of the adult damage; fleeting feeding visits by the adult moths could only be combated by coating all ripening fruit with a potent contact insecticide.

Fig. 9.317. Fruit-piercing Moths (*Othreis fullonia* and *Ophiusa tirhaca*); S. China.







0 1 cm *Othreis fullonia*

Sesamia calamistis Hamps.

Common name. Pink Stalk Borer
Family. Noctuidae
Hosts (main). Maize, sorghum, finger millet, rice, and sugarcane.

(alternative). Various species of wild grasses.

Damage. The larvae bore in the stem of the various graminaceous crops, weakening the stem mechanically, and reducing the crop yield. Early damage results in cereal 'dead-hearts' with the destruction of the central shoot, although tillering may compensate somewhat for this damage.

Pest status. A pest of sporadical importance on a wide range of graminaceous crops. Three other species also occur in E. Africa.

Life history. Eggs are laid on the leaf sheath in groups of up to 40. They hatch a week later and the larvae immediately start boring into the stem. The larval period is 6–10 weeks. The mature caterpillar is about 30 mm long and 3.5 mm broad, with a brown head and buff body with pink dorsal markings.

The pupal period lasts about ten days.

The adult moths are pale buff with darker markings on the forewings; the male is smaller (22–30 mm wingspan) than the female (24–36 mm), and the hind wings are white.

The total life-cycle takes from 30 days for completion, according to climatic conditions.

Distribution. Most of tropical Africa (CIE map no. A414).

Several other species of *Sesamia* also occur widely in Africa on the same range of host plants.

Control. Cultural control measures such as weeding, crop hygiene, removal of alternative hosts in the vicinity of the crop, do help to lower the pest populations.

The chemical control measures recommended are the same as listed on page 459.

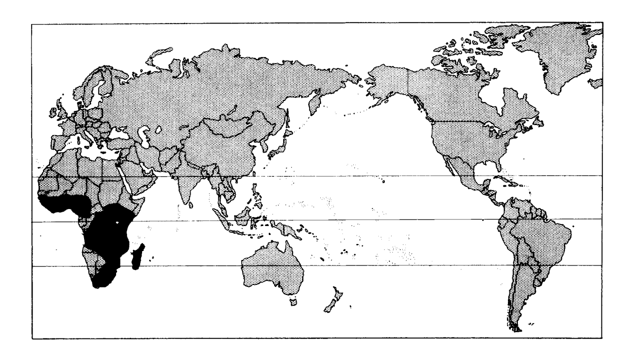
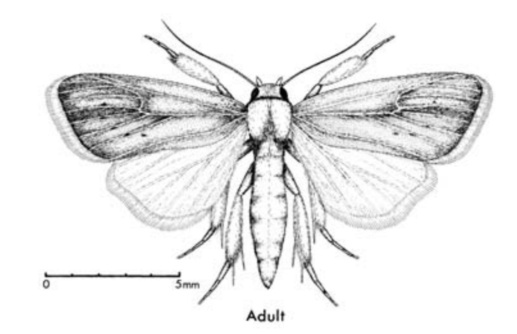


Fig. 9.318. Sesamia calamistis (Pink Stalk Borer); Kenya.



Sesamia inferens (Wlk.)

Common name. Purple Stem Borer
Family. Noctuidae
Hosts (main). Rice, and sugarcane. sorghum
(alternative). Maize, wheat, other, barley, oats, millets, cereals, *Eleusine coracana*, and many other grasses.
Damage. Small plants typically show 'dead-hearts', and older plants have extensive parts of the stem hollowed out, with a consequent physical weakening of the stem, and a reduction of crop yield.
Pest status. One of the major pests of rice and sugarcane; a polyphagous pest, and of importance on several other cereals in the tropics. Sugarcane is not a preferred host for oviposition – rice and grasses being preferred for this.
Life history. The eggs are bead-like, and laid in rows within the leaf-sheath; some 30–100 eggs per batch. Incubation takes about seven days.

The caterpillar is purple-pink dorsally and white ventrally; the head capsule is orange-red. After about 36 days the mature caterpillar is up to 35 mm long and 3 mm broad.

The pupa is dark brown with a purple tinge in the head region, and is about 18 mm by 4 mm. Pupation takes about ten days.

The adult moth is fawn-coloured with dark brown streaks on the forewings and white hindwings. The body length is 14–17 mm and wingspan up to 33 mm. The adults survive in the field for 4–6 days.

The total life-cycle takes 46–83 days.
Distribution. Pakistan, India, Bangladesh, Sri Lanka, S.E. Asia, China, Korea, Japan, Philippines, Indonesia, Papua New Guinea, West Irian and the Solomon Isles (CIE map no. A237).
Control. Control measures are as on page 459.

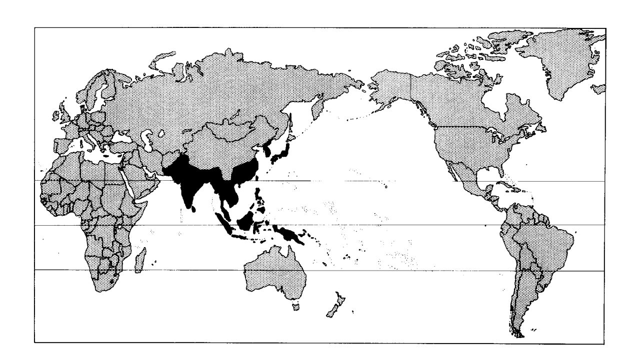
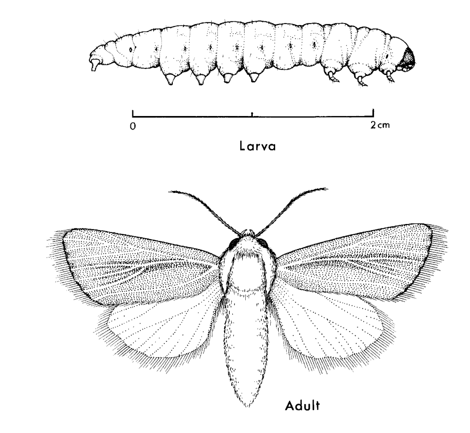


Fig. 9.319. Sesamia inferens (Purple Stem Borer); India.



Spodoptera exempta (Wlk.)
(= *Laphygma exempta* (Wlk.))

Common name. African Armyworm
Family. Noctuidae
Hosts (main). Grasses, maize, rice, and sorghum.
(alternative). Many cereals and wild grasses
Damage. Leaves of cereals are holed or eaten down to the midrib. Blackish velvety caterpillars are present which drop to the ground if disturbed.
Pest status. A major pest in outbreak years; outbreaks often follow rain in the hot season; a second outbreak generation may follow the first, though not necessarily in the same district. In non-outbreak years they are cryptically coloured and non-gregarious.
Life history. Eggs are laid in masses of one or more layers on the leaves, 10–300 or more. The egg mass is covered with hairs from the female. The eggs are white turning dark brown; hatching takes 2–5 days.

The caterpillar occurs in two forms; the gregarious outbreak phase is greyish-green when small, becoming blackish in the latter three instars. The fully grown caterpillar is black above with thin blue lines down the middle of the back; on each side of the black area are several greenish-yellow lines and a mid-lateral black line. The larval period lasts 14–32 days.

The mature caterpillar burrows into the soil to pupate. The pupa is brown or black in colour and about 17 mm long. It is enclosed in a delicate cocoon of soil particles held together by silk. The pupal period lasts 7–21 days.

The adult is a grey-brown night-flying moth with pale hindwings and a conspicuous kidney-shaped whitish mark on the forewings; the wingspan is about 28 mm. After a pre-oviposition period of 2–4 days the adult female may live a further seven days and lay 400 or more eggs.
Distribution. Africa, Madagascar, India, Sri Lanka, Burma, Malaya, Sumatra, Java, Philippines, Celebes, Hawaii, Borneo, Papua New Guinea, West Irian and Australia (CIE map no. A53 revised).
Control. There is no great advantage in killing mature caterpillars ready for pupation, as the second generation rarely occurs in the same area. The following insecticides are generally effective for armyworm control when applied as sprays or dusts: DDT, endosulfan, malathion, trichlorphon, and carbaryl.

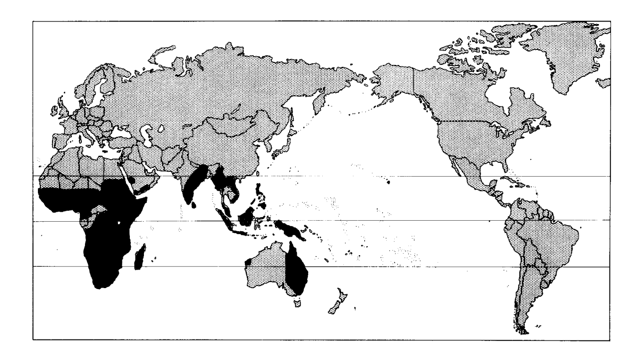
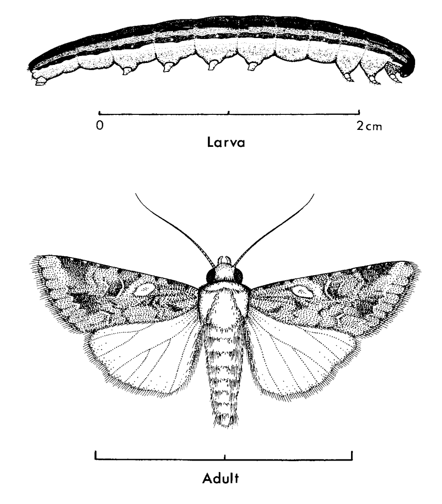


Fig. 9.320. Spodoptera exempta (African Armyworm); Kenya.





Armyworm damage to grass; Ethiopia

Control of Armyworms (Lepidoptera; Noctuidae).

Armyworms are the caterpillars of various Noctuidae, mostly *Spodoptera* spp., which under certain conditions of high population density behave gregariously; swarms will march from field to field devastatingly defoliating entire crops. Most species are migratory as adults (within Africa, and parts of Asia and the Americas) and are renowned for their spectacular population fluctuations which can lead to a severe outbreak year resulting in catastrophic damage. Egg batches are laid close together, and in a severe year the high density of caterpillars results in a rapid demolition of the local supply of food plants. When this happens the caterpillars may 'march' off over the ground like an 'army' to fresh feeding locations, feeding as they go. With large populations the ground may be literally covered with the gregarious 'marching' band of caterpillars, in many respects similar to a locust swarm.

The plants attacked are mostly Gramineae (cereals and grasses), but the genus *Spodoptera* (not all of which act as armyworms) is recorded feeding on plants from 40 different families, containing at least 87 species of economic importance (Brown & Dewhurst, 1975). In Africa *Spodoptera exempta* (African Armyworm) is of such importance that, following the severe outbreak in East Africa in 1961, there was established in 1962 an Armyworm Research Unit at EAAFRO (Kenya) in collaboration with COPR (London). It was to monitor field populations, migrations and flight behaviour in an attempt to predict population outbreaks and immigrations, and to co-ordinate co-operative control measures (E.S. Brown, 1972). This basic research is still being pursued by a unit at ICIPE, Nairobi, Kenya.

The term 'armyworm' is essentially behavioural (and physiological) and is not strictly taxonomic. Some species of *Spodoptera* do not act as armyworms, and species belonging to other genera of Noctuidae show swarming tendencies and may be classed as armyworms, including *Achaea* spp., *Ceraptery*x (especially *C. graminis*) and *Mythimna unipunctata*.

Some species are very versatile behaviourally and may behave quite differently under different circumstances. For example, *Spodoptera litura/littoralis* in small numbers feeds on the leaves and foliage of many plants, but will sometimes act as a cutworm and at other times will swarm gregariously and act as a typical armyworm. Common names for this species complex include Cotton Leafworm (Africa), Rice Cutworm (S.E. Asia), Fall Armyworm (China), Climbing Cutworm (Mediterranean) and Cluster Caterpillar (Australia); the diversity of common names for these two almost identical species (formerly regarded as one species) gives an indication of their behavioural diversity. Thus, it can be rather difficult to categorize particular species of pests according to the nature of the damage done, and care should be taken when using these terms.

Control of armyworms is often a large-scale or even international collaborative venture, and usually consists now of warnings based on light-trap or pheromone-trap catches, or prognostications based on prevailing meteorological conditions in certain areas, followed by u.l.v. drift spraying from light aircraft or helicopters or ground-based, hand-held sprayers. Effective insecticides used, to date, include DDT, carbanyl, endosulfan, fenitrothion, malathion, tetrachlorvinphos and trichlorphon. Dieldrin and BHC are also effective but seldom used because of environmental hazards associated with their widespread employment. Choice of chemical used depends in part upon the plants (crops) to be sprayed, and also local government restrictions (DDT may be banned).

Spodoptera exigua (Hbst.)

Common name. Lesser (Beet) Armyworm
Family. Noctuidae
Hosts (main). Sugar beet, alfalfa, cotton, upland rice.

(alternative). Asparagus, tobacco, groundnut, tomato, cabbage, potato, strawberry; many other crops, many flowers, and wild plants; totally polyphagous.

Damage. The larvae are gregarious and may feed in large swarms, when defoliation may be serious; young plants are killed but older plants may recover, and cereals tiller.

Pest status. A sporadic pest, but widespread and very polyphagous; at times of population outbreak damage to crops may be devastating, and entire crops destroyed.

Life history. Eggs are laid in clusters, several layers thick, and covered with hairs from the female abdomen. Each cluster contains 50–300 eggs; one female lays 300–900 eggs (up to 1700); hatching requires only 2–4 days.

The larvae are very gregarious, at first green, later becoming variable green or brown usually with a lateral stripe, and grow to a length of about 30 mm. Young larvae skeletonize the underside of the leaves, but later as they grow they eat the entire lamina. Larvae develop through their six instars in only 10–13 days.

Pupation takes place in the soil in an earthen cell and requires about six days. The adults are small brownish moths of wingspan 24–30 mm. They are rather nondescript in appearance and not easy to recognize. In parts of Europe it does not move far from the place of emergence, but in Canada it is an annual migrant from the USA.

One generation can be produced in as little as 21–24 days; in Africa and Israel there are usually eight generations annually.

Distribution. Recorded throughout Africa, southern Europe, India and southern Asia, Japan, Australasia, USA and Canada (CIE map no. A.302).

Control. The sporadic nature of the very large populations makes this a difficult pest to control, as infestations are usually serious by the time they are clearly evident. Cultural methods of control such as ploughing and burning of crop stubble, flooding infested fields, and removal of weeds all help to lower the pest populations. The insecticides generally recommended include dichlorvos, endrin, trichlorphon and toxaphene; the other chemicals used against noctuid caterpillars should also be effective.

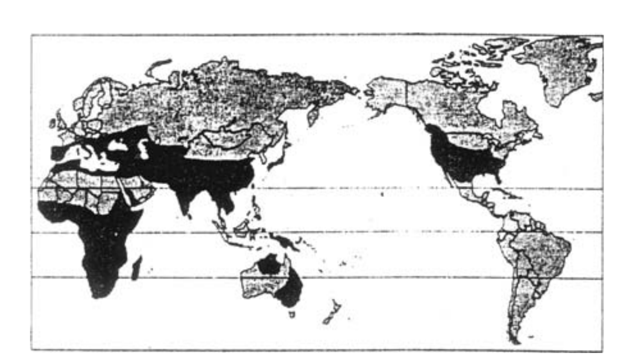
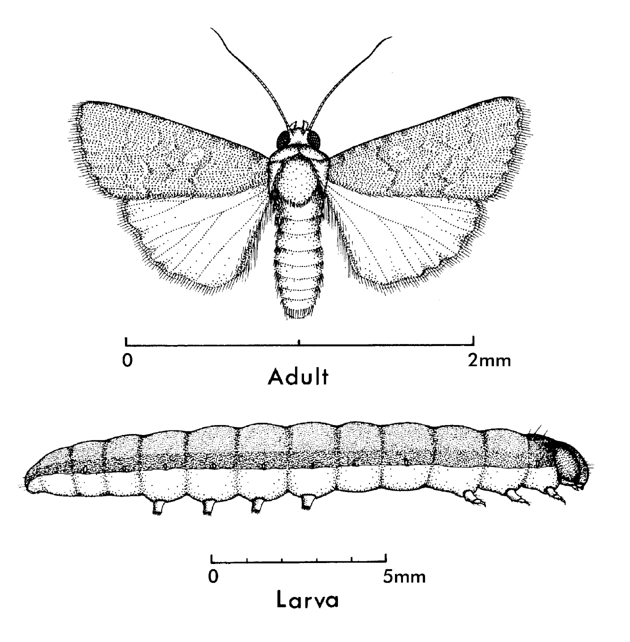


Fig. 9.321. Spodoptera exigua (Lesser Armyworm); Kenya.



Spodoptera littoralis (Boisd.)
(= *Prodenia litura* (F.) *auctt*.)

Common name. Was called 'Cotton Leafworm'
Family. Noctuidae
Hosts. A polyphagous pest attacking cotton, rice, tobacco, tomato, maize, castor, *Citrus*, mulberry, Cruciferae, legumes, many other vegetables, grasses, and ornamentals.
Damage. This caterpillar is essentially a leaf-eater, but does occasionally behave like a cutworm. Heavy infestations result in severe defoliation, but these are not of frequent occurrence. The young larvae are gregarious but they disperse as they become older.
Pest status. Not often a serious pest on any one crop but very frequently of minor importance on very many crops. Also called Mediterranean Climbing Cutworm.
Life history. The eggs are spherical, 0.3 mm in diameter, and laid on the undersides of leaves in batches of 100–300 and covered with hair-scales; one female lays from 1500–2000 eggs. Hatching takes 2–6 days, but can take up to 26 days in cooler regions.

The newly hatched larvae are gregarious, but later they disperse. Development through six instars takes 2–4 weeks. The caterpillars are pale green at first, becoming brown with dark markings, with yellow lateral and dorsal stripes. The length of the mature caterpillar is 35–50 mm.

Pupation takes place in the soil in an earthen cell, just beneath the surface; the pupa is dark red, 15–20 mm long. Pupation takes 6–11 days.

The adult has a whitish body with red tinges; the forewings are yellow-brown with varied white bands; the hindwings are whitish.

In the wet tropics breeding is virtually continuous with up to eight generations per year, the life-cycle taking 24–35 days.
Distribution. Africa, and the Mediterranean region, the Near East, and Madagascar (CIE map no. A232).

This species has for many years been inseparable from *S. litura* (the names being regarded as synonyms); the adults are only distinguishable by their genitalia; the larvae are very variable in colouration and cannot be definitely separated.
Control. See control of armyworms, page 473.

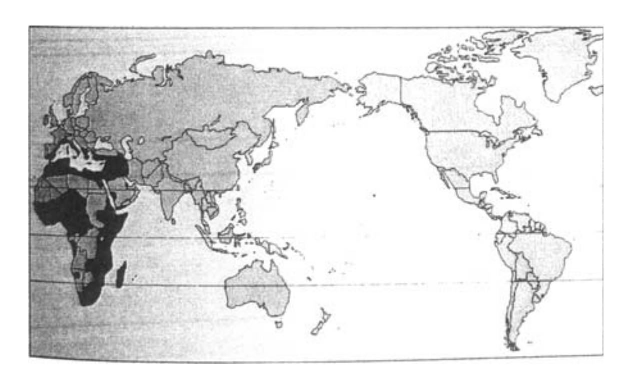
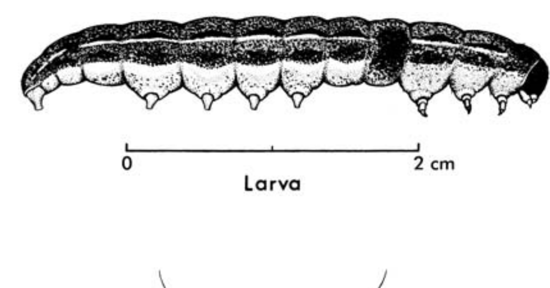
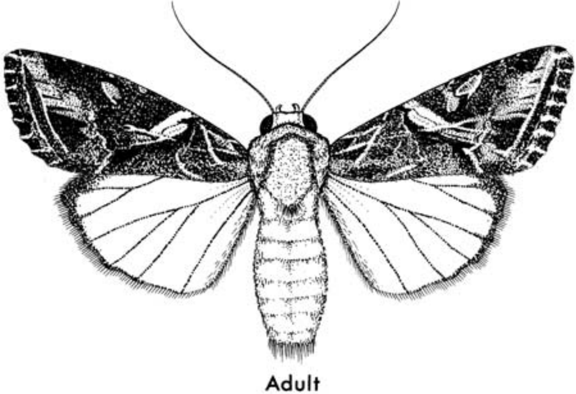


Fig. 9.322. Spodoptera littoralis (Cotton Leafworm); Kenya.





Spodoptera litura (F.)

(= *Prodenia litura* (F.) *auctt.*)

Common name. Fall Armyworm (Cluster Caterpillar; Rice Cutworm)
Family. Noctuidae
Hosts (main). A polyphagous pest of major status on cotton, rice, tomato, and tobacco.

(alternative). *Citrus*, cocoa, sweet potato, rubber, groundnut, castor, legumes, millets, sorghum, maize, and many vegetables.

Damage. As with *S. littoralis* this caterpillar is basically a leaf-eater, but does rarely act like a cutworm with crop seedlings. Heavy infestations can seriously defoliate a crop, but this is not a common happening.

Pest status. Not very frequently a serious pest on any one particular crop but of very regular occurrence on a very wide range of crops.

Life history. Eggs are laid underneath the leaves, in clusters of 200–300, and covered with hair scales. They hatch in 3–4 days.

The newly hatched caterpillars are tiny, blackish-green, and with a distinct black band on the first abdominal segment. For a while they are gregarious, but later they disperse. The caterpillars are nocturnal in habits and become fully grown in about 20 days, reaching a length of 40–50 mm. The mature caterpillar is stout and smooth with scattered short setae, dull greyish and blackish-green with yellow dorsal and lateral stripes. The lateral yellow stripe is bordered dorsally with a series of semi-lunar black marks. The head capsule is black.

Pupation takes place in the soil in an earthen cell, and the adult emerges after 6–7 days.

The whole life-cycle takes about 30 days, and in wet tropics there may be as many as eight generations.

Distribution. South and eastern Old World tropics, including Pakistan, India, Bangladesh, Sri Lanka, S.E. Asia, China, Korea, Japan, Philippines, Indonesia, Australasia, Pacific islands, Hawaii and Fiji (CIE map no. A61).

Only recently separated from *S. littoralis* by the genitalia of the adult moths – the larvae are not really separable. The two species are quite allopatric in distribution however.

Control. See control of armyworms, page 473.

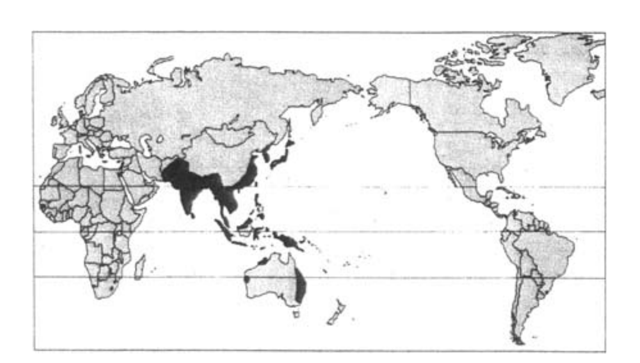
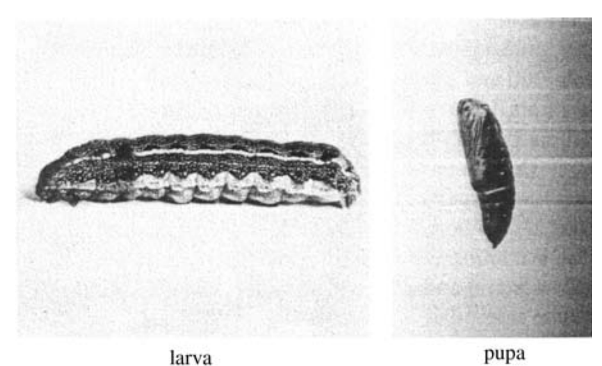
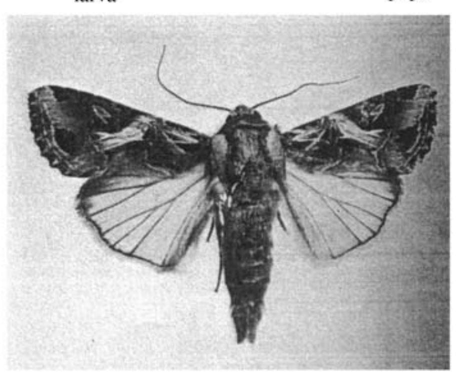


Fig. 9.323. Spodoptera litura (Fall Armyworm); S. China.





Spodoptera mauritia (Boisd.)

Common name. Paddy Armyworm
Family. Noctuidae
Hosts (main). Rice
(alternative). Maize, sugarcane, Cruciferae, and other species of Gramineae.
Damage. The small caterpillars eat the leaves of rice seedlings, at first nibbling the surface. Later as the caterpillars grow they become voracious and can destroy whole crops in a short period of time before moving on to other fields. The caterpillars are nocturnal and feed at night. Some older plants are attacked and damaged but this pest is really only a threat to seedlings.
Pest status. A sporadically serious pest of rice seedlings. This is sometimes called the 'Paddy Swarming Caterpillar'. In severe attacks whole crops are destroyed.
Life history. The spherical eggs are laid in clusters of 100–300 at the tips of upright leaves, and are covered with setae from the female body; hatching takes 3–9 days.

The newly hatched caterpillars are green, about 2 mm long, and difficult to see on the foliage. As they grow they become more brown, and after 15–24 days they are fully grown, and some 35–40 mm long. The head capsule is dark with a pale forked line; there are three lateral lines along the body with dark segmental marks above.

Pupation occurs in the soil; the pupa is dark brown and has two slender apical spines. Pupation takes 7–14 days.

The adult is a grey-brown moth, with 30–40 mm wingspan, and 15–20 mm long. The forewings are marked with several dark lines and a conspicuous black spot; the hindwings are whitish-brown with a thin dark margin.

The entire life-cycle takes 37–40 days typically.
Distribution. Madagascar, Tanzania, Uganda, Pakistan, India, Bangladesh, Sri Lanka, S.E. Asia, S. China, Philippines, Indonesia, Australia, Pacific islands, Hawaii and Fiji (CIE map no. A162 revised).
Control. See control of armyworms, page 473.

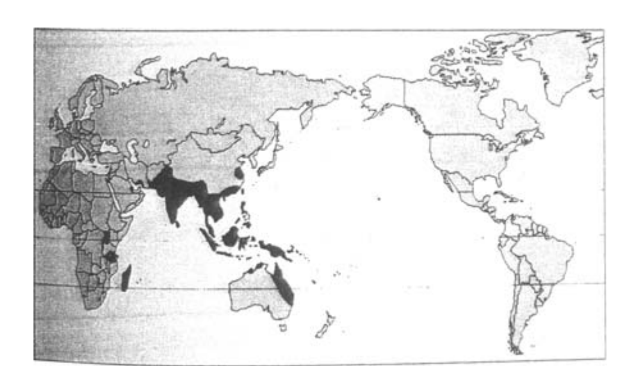
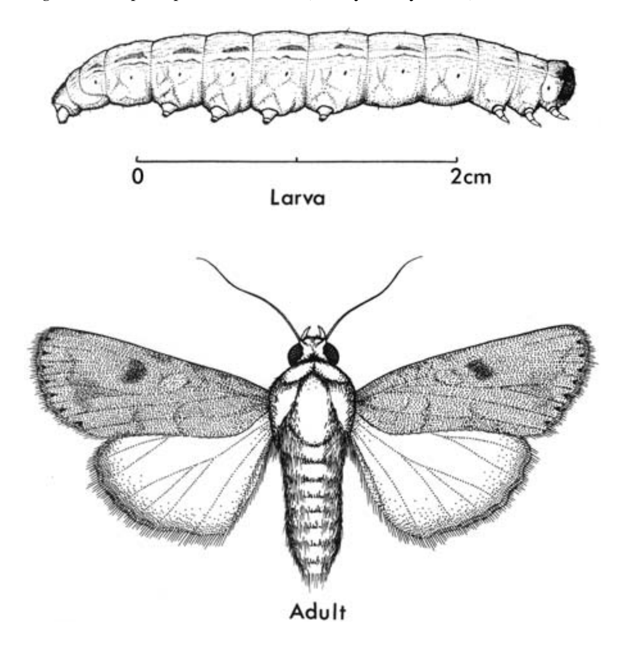


Fig. 9.324. Spodoptera mauritia (Paddy Armyworm); India.



Anomis flava (F.)
(= *Cosmophila flava* (F.))

Common name. Cotton Semi-looper
Family. Noctuidae (Plusiinae)
Hosts (main). Cotton
(alternative). Other Malvaceae, especially *Hibiscus, Abutilon*, and *Sida* spp., and *Althaea rosea* (hollyhock); also tomato and okra.
Damage. The caterpillar, which is a semi-looper (subfamily Plusiinae), eats the leaves of the cotton. Sometimes attacks are heavy and the plants may be completely defoliated.
Pest status. A pest of sporadic importance on cotton in the countries listed.
Life history. The eggs are laid singly on the leaves on which the larvae feed.

The larva is a semi-looper, and has only three pairs of prolegs. The body colour is pale yellowish-green with five fine lines longitudinally on the dorsal surface. When fully grown it is about 30 mm long.

Pupation takes place in the soil debris, or in a flap of leaf, between bract and boll, in a loose cocoon.

The adult is an attractive small moth with reddish-brown forewings traversed by two darker zigzagged bands. The hindwings are pale brown; wingspan is about 30 mm.

The total life-cycle takes 4–6 weeks. In China it is reported that the pupa overwinters.
Distribution. Found throughout the cotton-growing areas of Africa, Asia, and Australasia. CIE map no. A379 A related species *Cosmophila erosa* (Hb.) occurs in the New World.
Control. Recommended insecticides are diazinon, parathion and carbaryl, as foliar sprays to be applied when caterpillars are seen on the leaves of the crop.

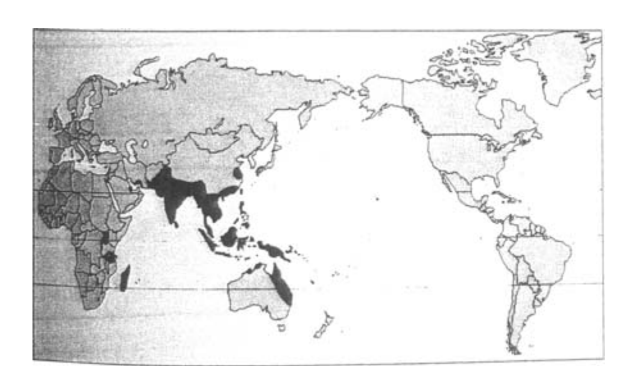
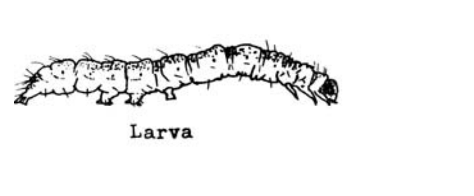
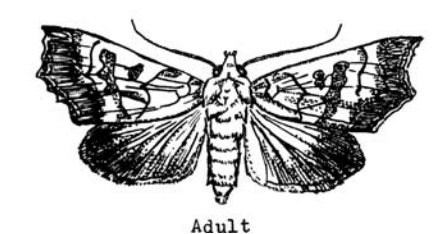


Fig. 9.325. Anomis flava (Cotton Semi-looper); Kenya.







Trichoplusia ni (Hb.)
(= *Autographa brassicae* Riley)
(= *Plusia ni* Hb.)

Common name. Cabbage Semi-looper
Family. Noctuidae (Plusiinae)
Hosts (main). *Brassica* spp. and other Cruciferae.

(alternative). Cotton, legumes, Solanaceae, Opium Poppy, sweet potato, some cucurbits, and many others.

Damage. The larvae eat irregular holes in the leaf lamina, and in cabbage they tend to attack the heart, eating a great deal and contaminating with frass.

Pest status. A serious pest on *Brassica* spp. throughout most parts of the world, though its pest status and hosts attacked tend to vary.

Life history. Eggs are laid singly on the underside of the host plant leaves, and hatch after 2–3 days.

Larvae are basically green in colour, with a thin, white, lateral line, and two white lines along the middle of the back. There are two pairs of prolegs so the caterpillars walk with a 'looping' action characteristic of the Plusiinae. Larval development takes some 30–35 days, usually five instars.

Pupation takes place within a silken cocoon, usually in the leaf litter or crop debris, and development takes about 15 days under optimum conditions.

The adult is a dark brownish moth with two small white markings on the forewing, sometimes resembling a figure '8', wingspan is about 35 mm. Adults live for about three weeks.

There is no evidence for diapause, in temperate areas the caterpillars continue to be active at low temperatures; generally flight ceases at about 16°C and larval development at about 12°C.

In warm regions there may be five generations per year, or more as a result of continuous breeding.

Distribution. Very widely distributed throughout the tropics and subtropics, with the exception of Australasia, and extending up into the warmer parts of S. Canada and Europe (CIE map no. A328) where populations are reinforced by annual migrations.

Control. Many natural predators and parasites are recorded for this species, and field mortality may sometimes be high. Nuclear Polyhedrosis Virus and *Bacillus thuringiensis* are effective against this pest.

Ultra-violet light traps, used with sex pheromone, have controlled populations in some localities in the USA, but this is more a diagnostic tool than control measure.

Chemical control has been difficult to achieve; resistance is established to many insecticides including DDT, carbaryl, parathion, methomyl, and others.

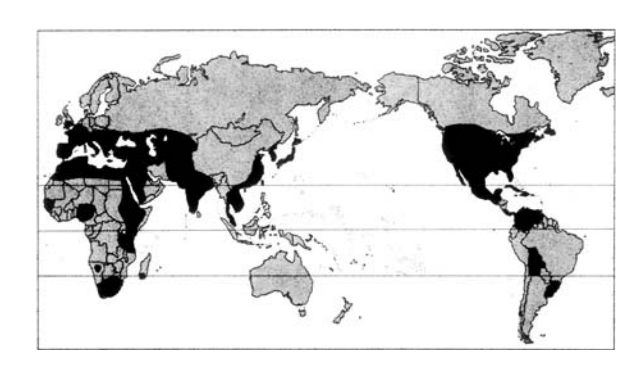
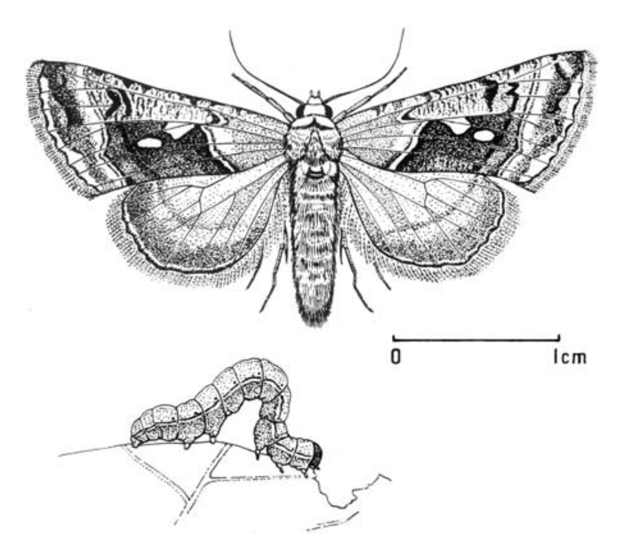


Fig. 9.326. Trichoplusia ni (Cabbage Semi-looper); S. China.



Xestia c-nigrum (L.)
(= *Amanthes c-nigrum* L.)

Common name. Spotted Cutworm (Setaceous Hebrew Character)
Family. Noctuidae
Hosts. A polyphagous cutworm showing no definite host specificity; recorded damaging celery, carrot, sugarbeet, cotton. Cruciferae, flax, grapevine, tobacco, tomato, various legumes, blueberry, chrysanthmum etc.; also many wild hosts including several common ruderals.
Damage. Feeding larvae eat the leaves of the host plants and also act as cutworms and destroy seedlings, as well as eating roots in the soil.
Pest status. One of the less important cutworms, but totally polyphagous and very widespread, and regularly encountered.
Life history. Eggs are laid singly on the food plant or on the surrounding soil; the average number laid per female is less than 100; hatching requires 8–9 days.

The larvae are bright green at first, becoming grey-brown or olive-brown, with a series of black abdominal marks subdorsally and a whitish transverse band on segment 8; spiracles are white, and a broad yellowish spiracular stripe. Fully grown the larvae measure about 37 mm. In habits the larvae are more similar to armyworms than to cutworms, but in general their biology is not well known. It is thought that most feed throughout the autumn and winter and again the following spring, pupating in April or May; adults are seen mostly in the autumn, but there is a small emergence usually in May and June.

The adults are somewhat variable in colour, being usually greyish or brownish, with a distinctive pattern on the forewing; the hindwing is whitish but darker distally; wingspan is 35–45 mm.

In Canada and northern Europe they are probably bivoltine, but in warmer regions there may be many generations annually. In some regions this species is quite strongly migratory.
Distribution. Found throughout Europe (up to Finland), and Asia from India to Korea and Japan, also N. Africa, Java, and N. America (CIE map no. A.400).

Several other species of *Xestia* (= *Amanthes*, etc.) are recorded as crop pests throughout Europe and Asia.
Control. Natural levels of parasitism are reported to be very high in some locations. Control is not often required, but on these occasions sprays of the chemicals mentioned on the previous page should suffice.

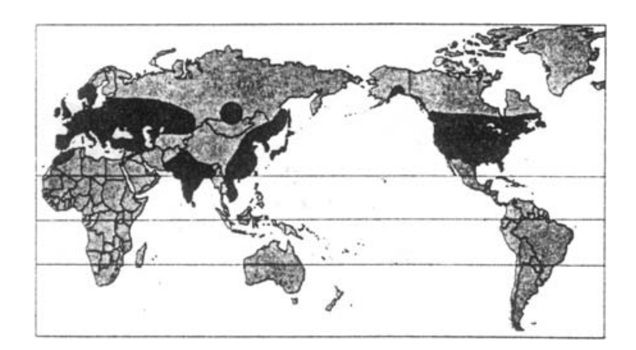
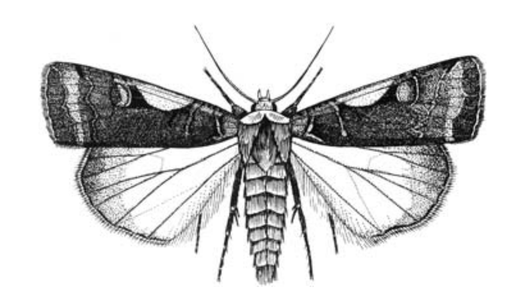


Fig. 9.327. Xestia c-nigrum (Spotted Cutworm); Cambridge, U.K.



Tussock moths (Lepidoptera; Lymantriidae)

A family of moderate-sized moths, mostly of a drab or white coloration, hairy and heavy-bodied, the females typically bear a thick anal tuft of scale-hairs which are detached and used to cover the egg mass after oviposition. In a few species the female has wings vestigial or even absent (*Orgyia* spp.).

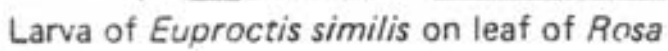
The larvae are stout-bodied and bristly caterpillars, sometimes strikingly coloured; they are general defoliators and some are very polyphagous. Most are damaging to forest trees (both conifers and deciduous trees), but some feed on fruit trees and various woody shrubs. In a few species the eggs are laid on the ground and the young larvae have to climb the trees in order to reach their food source (leaves). These species (of *Lymantria*) can clearly be controlled by either sticky bands on the tree trunk or by band-spraying the trunks with dieldrin.

Some of the more important agricultural pest species include:
Dasychira mendosa (Hb.) – polyphagous; India and southern Asia.
Dasychira spp. (400 species are known) – on many hosts; Old World and New World.
Euproctis chrysorrhoea (L.) – (Brown-tail Moth) polyphagous; Europe, Asia, USA (CIE map no. A.362).
Euproctis similis (Fue.) – (Yellow-tail Moth) polyphagous; Europe and Asia (CIE map no. A.388).
Euproctis fraterna (Moore) – polyphagous; India.
Euproctis pseudoconspersa Strand – (Tea Tussock Moth) Japan.
Euproctis spp (600 species are known) – polyphagous; Old World.
Lymantria dispar (L.) – (Gypsy Moth) polyphagous; Asia, Europe, Canada and USA (CIE map no. A.26).
Lymantria lapidicola (H.-S.) – (Almond Tussock Moth) Asia Minor.
Lymantria monacha (L.) – (Nun Moth) polyphagous on trees; Europe and Asia (CIE map no. A.60).
Lymantria spp. (150 species recorded) several on cultivated plants; Old World.
Orgyia antiqua (L.) – (Vapourer Moth) polyphagous; Europe, Asia, USA.
Orgyia spp. (60 species) several are polyphagous pests of cultivated plants; most known from the Holarctic Region.
Perina nuda (F.) – (Fig Tussock Moth) India, S.E. Asia, China.

In the figure is shown a larva of *Euproctis similis* on a leaf of *Rosa* sp.
The genera *Dasychira* and *Euproctis* with their vast number of recorded species (400 and 600 respectively) are both in need of taxonomic revision; it has been suggested that *Dasychira* be restricted to some New World species.

Fig. 9.328. (a) *Euproctis similis* (Yellow-tail Moth); England. (b) Typical Tussock Moth caterpillar ("*Euproctis*" sp.); Sarawak.




Larva of *Euproctis similis* on leaf of *Rosa*



Order **HYMENOPTERA**

An enormous group of about 100 000 species, comprising the ants, bees, wasps, chalcids, ichneumonids, etc. They all possess two pairs of membraneous wings, the hind-wings smaller and interlocking with the fore-wings by small hooks. The mouthparts are typically for biting, but sometimes for sucking. The abdomen is typically basally constricted and its first segment fused with the metathorax. An ovipositor is always present, and modified for sawing, piercing or stinging. Metamorphosis is complete; the larva is generally apodous with a more or less well-defined head.

Family **Tenthredinidae**

(Sawflies) This is the largest family of sawflies containing about 4000 species. The eggs are usually laid in young shoots or leaves, and the saw of the ovipositor modified according to its role. The larvae are typified by having on the abdomen six pairs of prolegs in addition to the terminal claspers. The larvae are either exposed on the leaf surface, sometimes gregarious, or else they make galls, or live inside the stems. A few species have slug-like larvae. Pupation takes place in a silken cocoon in the soil.

Family **Formicidae**

(Ants) A large family containing all the described species of ants – some 3500 species in total. They are usually social insects with well-defined castes, including workers, soldiers, and royal forms. Some ants do cause direct damage to crops but others are most important as a nuisance to the plantation workers by their biting and stings. Some ants are also of considerable importance in their attendance on various homopterous pests such as aphids, mealybugs and scale insects – generally their presence is thought to keep the bugs free from predation and parasitism. Some of the aggressive arboreal species (*Oecophylla* spp.) that may attack field workers are also predaceous and will kill some species of pests in trees and palms. But the arboreal ants may in turn be killed or driven away by certain more aggressive ground-nesting species that forage in trees (*Anoplolepis* and *Pheidole* spp.).

Family **Vespidae**

(Wasps) A large family of social insects, mostly tropical in distribution, but some are temperate. Adults and larvae are basically predaceous, and so the adult wasps are part of the local natural predator complex and important in the natural control of pest species. However, the adults also are attracted to sugar, and can be found eating honey-dew; they also attack ripe and ripening fruits for the sweet sap and may do considerable damage in some orchards. Some species, such as *Polistes*, tend to nest in bushes and small trees, close to the ground and are very aggressive if disturbed and fiercely attack any disturbers.

Athalia spp. (10+)

Common name. Cabbage Sawflies
Family. Tenthredinidae
Hosts (main). Brassicas of all species
(alternative). Other members of the Cruciferae.
Damage. Leaves are eaten by the larvae, often leaving only the midrib. Blackish larvae are present on the plant and they fall to the ground if the plants are shaken.
Pest status. A sporadically serious pest of all cruciferous crops; turnip, chinese cabbage, kale and crambe are particularly susceptible to attack.
Life history. Eggs are laid singly in small pockets cut in the leaf by the female sawfly.

The larva closely resembles a lepidopterous caterpillar, the important difference is that these sawfly larvae have six pairs of prolegs on the abdomen instead of the four found in caterpillars. The full-grown larva is about 2.5 cm long, and is oily black or green; black specimens often have yellow spots. The head is shiny black and that part of the body just behind the head is often slightly swollen, giving the larva a humped appearance.

The full-grown larva burrows into the soil and spins a tough silk cocoon to which particles of soil adhere. The yellowish pupa forms within the cocoon.

The adult remains in the cocoon for a while before it emerges and pushes its way through the soil to the surface. It is about 0.5 cm long and has a dark head and thorax with a bright yellow abdomen. The adults may often be seen flying about slowly, just above the crop.
Distribution. Great Britain, and Europe from Spain through to Siberia, China and Japan, down to Asia Minor, N. Africa, E. and S. Africa, and S. America. More than ten species are known.
Control. Destruction of wild crucifers on the head-lands will help to keep the pest population down.

The following pesticides have been found to be effective as foliar sprays: DDT, carbaryl and pyrethrum.

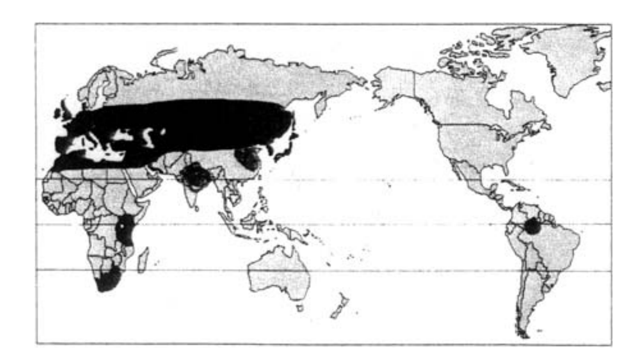
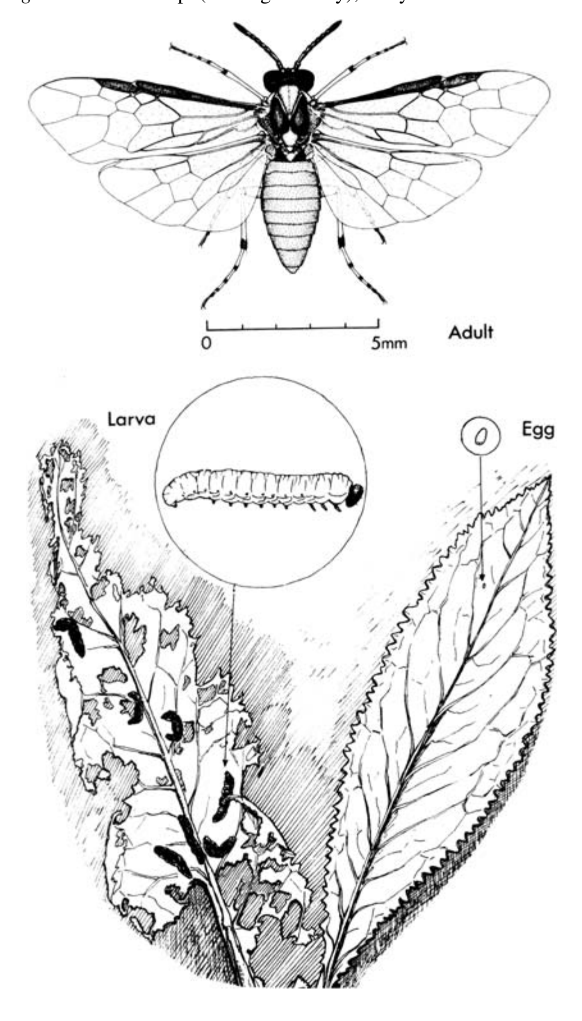


Fig. 9.329. Athalia sp. (Cabbage Sawfly); Kenya.



Sawflies (Hymenoptera; Symphyta)

This large group constitutes a sub-order within the Hymenoptera; the members possess various morphological and anatomical characters in common, and the distinctive larvae are phytophagous (except for a few parasitic on wood-boring beetle larvae), and quite a large number cause damage to cultivated plants. However, the majority are leaf eaters on trees in the north temperate deciduous forests and the taiga coniferous forests of the Holarctic Region. The group is worldwide in distribution, although mainly north temperate (Holarctic); representatives are to be found in every country; some species are actually sub-arctic, either in grass stems or eating conifer needles.

The adults are small to medium-sized, often black, black and yellow, or blue in body colour, with hyaline wings. The female has a saw-like ovipositor with which she deposits eggs singly into the host plant tissues (hence their common name of 'sawflies'); the ovipositor is usually concealed under the tip of the abdomen but in a few species of woodwasps it protrudes distinctively. In this group the abdomen is broadly sessile, and there is no constriction between segments 1 and 2.

The larvae are basically caterpillars (eruciform), but distinct from those of Lepidoptera in having 5–8 pairs of abdominal prolegs (in addition to terminal claspers); they are often spotted whereas Lepidoptera are more usually striped. Species living inside plant tissues usually have reduced legs (as with other insect borers), and a few of the leaf eaters are slug-like with tiny legs. Most of the larvae are solitary (after the first instars), but a few live and feed gregariously on leaves in a most characteristic manner (they are arranged around the leaf lamina edge and when disturbed they stop feeding and elevate the abdomen). The species regarded behaviourally as 'solitary' may occur in dense populations which can defoliate entire trees, but there is no interaction between adjacent larvae.

The life-styles of the larvae vary considerably, and this directly relates to the type of damage done to the plants, as follows.

(a) Leaf eaters: solitary – most Tenthredinidae, Diprionidae, etc.
gregarious – *Croesus, Hemichroa*, etc.
(b) Leaf skeletonizers: *Caliroa, Endelomyia* (Caliroini).
(c) Leaf rollers: *Blennocampa*.
(d) Leaf miners: *Metallus, Fenusa*, etc.
(e) Leaf gall makers: *Pontania* on *Salix* leaves.
(f) Shoot and stem borers: in Gramineae – Cephidae.
in woody shrubs – Cephidae, etc.
(g) Fruit borers: *Hoplocampa* spp. (Tenthredinidae).
(h) Wood borers (tree trunks and branches):
evergreens – many Siricidae.
deciduous trees – *Tremex* (Siricidae)

Pupation takes place inside a cocoon, usually in the soil, but the wood wasps pupate inside the larval tunnel, as do the stem borers.

In the following list a few small families which do not contain pest species of importance have been omitted.

Sawfly pest species

Some of the more important pest species of sawflies are listed, in their usual taxonomic sequence, below.

Pamphilidae
Neurotoma saltuum L. – (Social Pear Sawfly) Europe.
Neurotoma spp. – (Plum (etc.) Sawflies) USA, Canada.
Pamphilius spp. – (Blackberry (etc.) Sawflies) USA, Canada.

Siricidae (wood wasps)
Sirex spp. (3+) – (Blue Woodwasps) conifers; Europe, Australia, USA, Canada.
Tremex spp. – deciduous trees; Europe, Asia, USA, Canada.
Urocerus gigas (L.) – (Giant Woodwasp) Europe, Asia.

Cephidae (stem sawflies)
Cephus cinctus Norton – (Wheat Stem Sawfly) Canada, USA (CIE map no. A.29).
Cephus pygmeus (L.) – (European Wheat Stem Sawfly) Europe, W. Asia, USA, Canada (CIE map no. A.30).
Hartigia trimaculata Say – (Blackberry Shoot Sawfly) USA, Canada.
Janus integer (Norton) – (Currant Stem Girdler) USA.
Syrista similis Mac. – (Rose Stem Sawfly) Japan.
Trachelus tabidus (F.) – (Black Grain Stem Sawfly) USA.

Argidae (rose sawflies)
Arge mali Tak. – (Apple Argid Sawfly) Japan.
Arge ochropus (Gm.) – (Large Rose Sawfly) Europe.
Arge pagana (Panzer) – (Rose Sawfly) Europe, Asia, Japan (see figure on page 462).
Arge spp. – (Rose (Birch, etc.) Sawflies) Europe, Asia, Japan, N. America.

Cimbicidae
Cimbex spp. – (Elm Sawflies) Europe, Asia, USA.
Palaecimbex carinulata Konow – (Pear Cimbicid Sawfly) Japan.

Diprionidae (conifer sawflies)
Diprion pini (L.) – (Pine Sawfly) Europe, Asia.
Diprion spp. – (Pine (etc.) Sawflies) Europe, Asia, Canada, USA.
Neodiprion spp. (15+) – (Pine (etc.) Sawflies) Europe, Asia, Japan, Canada, USA (CIE map no. A.98).

Tenthredinidae
Allantus albicinctus Mats. – (Strawberry Sawfly) Japan.
Allantus cinctus (L.) – (Banded Rose Sawfly) Europe, USA.
Allantus nakubusensis Tak. – (Cherry Sawfly) Japan.
Ametastegia glabrata (Fallen) – (Dock Sawfly) Europe, Canada.
Apethymus kuri Tak. – (Chestnut Sawfly) Japan.
Athalia japonica Klug – (Cabbage Sawfly) Japan.
Athalia lugens Marlatt – (Cabbage Sawfly) Japan.
Athalia rosae (L.) – (Cabbage Sawfly) Europe, Asia, Japan.

Blennocampa caryae (Norton) – (Butternut Woollyworm) USA.
Blennocampa pusilla (Klug) – (Leaf-rolling Rose Sawfly) Europe (see figure on page 462).
Caliroa castaneae (Roh.) – (Chestnut Slug Sawfly) USA.
Caliroa cerasi (L.) – (Pear Slug Sawfly) Europe, Asia, Japan, Canada, USA (CIE map no. A. 175).
Caliroa matsumotonis (Har.) – (Peach Slug Sawfly) Japan.
Cladius spp. (4) – (Antler (Rose) Sawflies) Europe, Japan, USA.
Croesus castaneae Roh. – (Chestnut Sawfly) USA.
Croesus septentrionalis (L.) – (Hazel Sawfly) Europe, USA (see figure on page 462).
Croesus spp. – (Birch/Alder Sawflies) Europe, Asia, Japan, USA.
Dolerus ephippiatus Smith – (Wheat Sawfly) Japan.
Dolerus lewisi Cam. – (Wheat Sawfly) Japan.
Dolerus spp. – (Cereal and Grass Sawflies) Canada, USA.
Empria maculata (Norton) – (Strawberry Sawfly) USA, Canada.
Endelomyia aethiops (F.) – (Rose Slug Sawfly) Europe, USA.
Erythraspides vitis (Harris) – (Grape Sawfly) USA.
Fenusa spp. – (Birch/Elm Sawflies) USA.
Hemichroa crocea (Geo.) – (Striped Alder Sawfly) USA.
Hemichroa sp. – (Camphor Sawfly) China.
Hoplocampa brevis (Klug) – (Pear Sawfly) Europe (CIE map no. A.169; page 458).
Hoplocampa cookei (Clarke) – (Cherry Fruit Sawfly) USA.
Hoplocampa flava (L.) – (Plum Sawfly) Europe, Asia, Minor (CIE map no. A.168; page 458).
Hoplocampa minuta (Christ) – (Small Plum Sawfly) Europe, Asia Minor (CIE map no. A.167).
Hoplocampa pyricola Roh. – (Pear Fruit Sawfly) Japan.
Hoplocampa testudinea (Klug) – (Apple Sawfly) Europe, Asia, Canada, USA (CIE map no. A. 166; page 458).
Metallus albipes (Cam.) – (Raspberry Leaf-mining Sawfly) Europe.
Metallus pumilus Klug – (Raspberry Leaf-mining Sawfly) Europe.
Monophadnoides genicultatus (Hartig) – (Raspberry (Geum) Sawfly) Europe, USA.
Nematus leucotrochus Hart. – (Pale Spotted Gooseberry Sawfly) Europe.
Nematus olfasciens Benson – (Black Currant Sawfly) Europe (page 459).
Nematus ribesii (Scop.) – (Gooseberry Sawfly) Europe (page 459).
Nematus spp. (many) – oaks, poplars, willows, etc.; Europe, Asia, USA, Canada.
Pachynematus spp. – (Wheat (and Grass) Sawflies) Holarctic (subarctic).
Pontania spp. – (Willow Redgall Sawflies) Europe, USA.
Priophorus pallipes Lep. – (Plum Leaf Sawfly) Europe.
Pristiphora abbreviata (Hartig) – (California Pear Sawfly) USA.
Pristiphora pallipes Lep. – (Small Gooseberry Sawfly) Europe, USA.
Pristiphora spp. – (Larch/Oak Sawflies) Europe, Asia, Japan, Canada, USA (CIE map no. A.97).
Pristiphora spp. – (Birch Sawflies) Europe, USA, Canada.
Takeuchiella pentagona Malaise – (Soybean Sawfly) Japan.
Tenthredo spp. – polyphagous; Europe, Canada, USA.
Trichiocampus pruni Tak. – (Cherry Sawfly) Japan.

Control of Sawflies

Of the sawfly species that are crop pests, it is almost invariably the iarvae that do the damage, though some may be done to plant tissues by the action of the female ovipositor. So control measures are directed against the larvae on the crop plants. Most commercial orchards have a regular spraying programme with organophosphate materials, applied at or just after petal-fall, against the local pest complex, and this usually controls the leaf and fruit-eating sawfly larvae as well as other pests. Occasionally sawfly outbreaks do require specific treatment.

For many species it has been recently reported that γ-HCH still gives the best control, applied as a high-volume spray at petal-fall, unless resistance to this chemical has developed. Generally now resistance to HCH is quite widespread.

The chemicals generally available for control of sawfly larvae on foliage and fruits include the following: γ-HCH, derris, azinphos-methyl+demeton-*S*-methyl-sulphone, chlorpyrifos, dimethoate, malathion, oxydemeton-methyl, pirimiphos-methyl, and the pyrethroids cypermethrin, deltamethrin and permethrin.

Usually control recommendations require one of these chemicals to be applied within seven days, or thereabouts, of about 80% petal-fall, as a full-cover high-volume spray. Occasionally a second spray may be required 14 days after first application. On dense bushes or trees it is essential that the spray penetrates to the centre of the bush foliage. This treatment should kill most larvae, which at the time of the first spray should mostly be newly-hatched and small in size. If the fruitlets have already been penetrated by the young larvae then a systemic insecticide should be used. For the species that remain on the foliage, contact and stomach-acting insecticides are most effective.

Precise choice of insecticides to be used depends in part upon which species of sawfly is involved, and on which crop, and also on weather conditions at the time of spraying. If there is any doubt as to choice of candidate insecticide then the local Ministry of Agriculture staff should be consulted.

Nematus spp.
(N. olfasciens Benson)
(N. ribesii (Scopoli))

Common name. Black Currant Sawfly; Gooseberry Sawfly
Family. Tenthredinidae
Hosts. Black, red and white currants; gooseberry, red and white currants (respectively).
Damage. The feeding larvae eat the leaves and cause defoliation, usually on one branch at a time, starting in the centre of the bush near to the ground; in heavy attacks the entire bush may be defoliated.
Pest status. A very large and widespread genus causing defoliation on a wide range of trees and bushes; these two species are quite damaging to currants and gooseberry bushes.
Life history. Eggs are laid on the underneath of leaves, in shallow slits along the main veins; 20–30 eggs may be found on a single leaf; the oval eggs are about 1 mm long and quite conspicuous; hatching requires about one week.

The young larvae emerge in May, and initially feed gregariously; but as they grow they gradually disperse over the bush. The body is green with small black spots, and the head is black (green in *olfasciens*). When fully grown (after 3–4 weeks) the larvae become pale green with an orange patch on the thorax; they leave the bush to pupate in a cocoon in the soil, at a depth of 5–8 cm; pupation takes 10–21 days. There are usually three generations per year in the UK, with considerable overlap so that all stages may be found on the same bush at the same time. The larvae of the last generation overwinter inside the pupal cocoons in the soil.

The adults are very similar, with a black head and thorax and yellow abdomen, and clear transparent wings 10–16 mm diameter.
Distribution. These two species are recorded from Europe, and *ribesii* is reputedly worldwide in distribution, but their precise ranges are not known.

Also included here are the other pest species of *Nematus*, namely:
Nematus leucotrochus Hart. – (Pale Spotted Gooseberry Sawfly) Europe.
Nematus salicis (L.) – (Willow Sawfly) Europe.
Nematus spiraeae Z. & B. – (Spiraea Sawfly) Europe.
Nematus spp. – on oak, poplars, willows, etc.; Europe and N. America.

There are at least 40 species of *Nematus* recorded from the UK alone, and a similar number in N. America.

On currants and gooseberry bushes, on both continents, there may be several other species of sawflies feeding on the foliage.
Control. When control is needed the usual recommendation is a spray of azinphos-methyl, derris, fenitrothion or malathion, etc., aimed at the centres of the bushes.

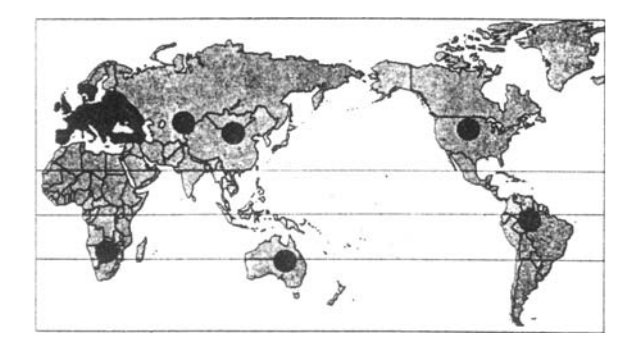
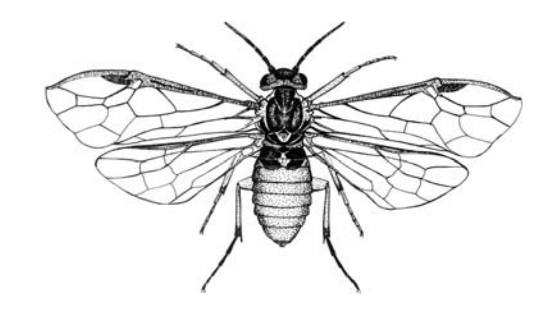


Fig. 9.330. Nematus sp. (Currant sawfly); Cambridge, U.K



Atta spp.

Common name. Leaf-cutting Ants (Fungus, or Parasol Ants)
Family. Formicidae (Attini)
Hosts (main). *Citrus*, cocoa, coffee, maize.

(alternative). Cotton, cassava, mango, beans, sweet potato, groundnut, banana, pineapple, rice, wheat, etc., and many forest trees (especially teak and *Pinus*) and many grasses and wild plants.

Damage. They are generally polyphagous feeders, but certain species show host-specificity and some prefer monocotyledonous plants whilst others prefer dicotyledonous ones. The foraging adult ants cut pieces of living leaf foliage and carry them back to the nest for construction of fungus gardens. Severe attacks result in total defoliation, and many trees die.

Pest status. Damage in the neotropics was estimated by Cramer (1967) to be US $ 1000 million annually, due to defoliation by species of *Atta* and *Acromyrmex*. There are 18 species of *Atta*, collectively regarded as serious pests in the region between Texas, USA, and northern Argentina, because of their defoliation of cultivated plants.

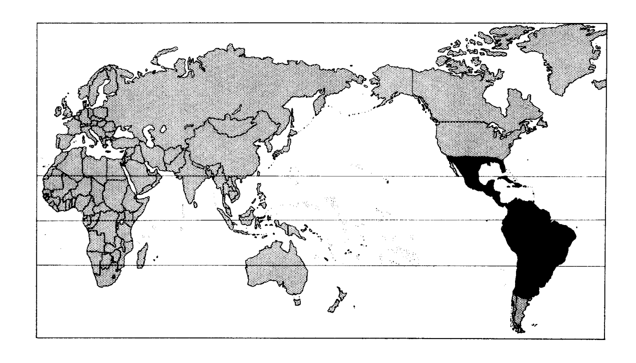
Life history. The tribe Attini are fungus-growing ants. The largest individuals belong to the genera *Atta* and *Acromyrmex* and are known as leaf-cutter ants because they use pieces of leaf tissue for the construction of their underground fungus gardens. The ants are colonial, living in large underground nests. *Atta* spp. are apparently forest dwellers for most nests are located in the forest areas, and they are most serious as pests in cultivated land near forest edges. The nest is generally large, measuring up to 10–15 m in diameter, 4 m in depth, and containing up to 2 million ants. Queens have been recorded living up to 20 years, and so many nests may be long-lived. The nest area is evident as a slightly raised bare mound with numerous entrance holes.

The nest colony consists of many small underground interlinked chambers which contain the fungus gardens constructed out of chewed leaf fragments mixed with saliva. On this organic base the ant fungus mycelium develops, and the ants feed on the staphylae which are specialized swollen hyphae. The larvae and pupae are kept in the fungus chambers where they are nursed by the smallest worker ants.

The workers (sterile females) occur as several distinct size castes; the smallest remain in the nest for nursing and cultivation duties, and the largest go out to forage for food under the protection of the large aggressive soldiers.

The ants forage communally using pheromone trails and cut pieces of living leaf material; they then carry each piece back to the nest, where it is chopped up into small pieces and stored in special chambers. *Atta* spp. generally forage for distances up to 150 m from the nest.

Sexual adults are produced once annually, and the nuptial/dispersal flights occur usually in the middle of the rainy season; dispersal has been recorded up to 10 km. *Atta* spp. generally produce a small number of large queens; after founding a new colony sexuals are not produced until after three years.



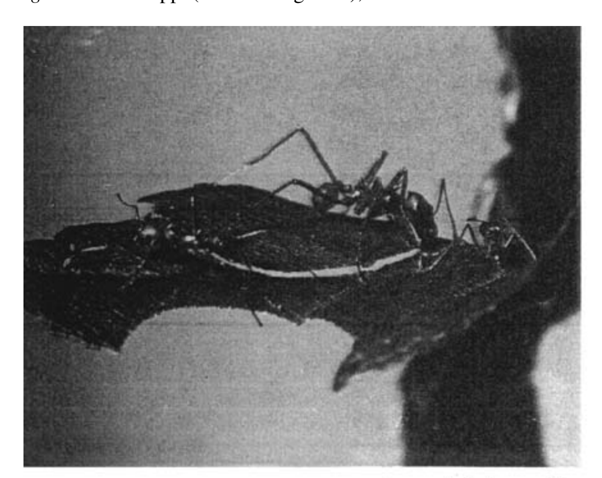
Distribution. These ants are confined to the New World tropics. The 18 species of *Atta* occur as a group throughout 23 countries from Texas (USA), Mexico, W. Indies, C. America and S. America down to Uruguay and northern Argentina. Each country usually has just a few species of *Atta*, but Brazil has a total of nine species. The most important species is *Atta cephalotes* (L.), found in 17 countries.

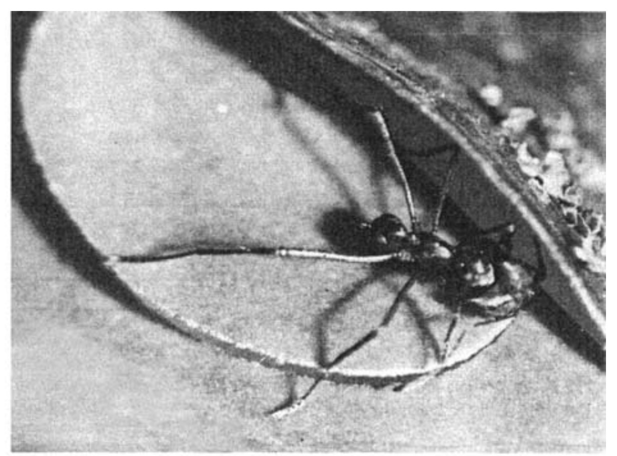
Control. Because of the feeding habits of these ants, and their colonial life-style, destruction of the nest population is generally aimed at rather than any direct plant protection. Chemical control is of two basic types; poison baits or organochlorine compounds injected into the nest tunnel system.

Baits are either Mirex in a pellet formulation, or else a matrix (base) of organic material with aldrin or chlordane as the toxicant. The matrix may be citrus pulp (meal) or other meals, and may have vegetable oils added. Recent work is testing the use of trail pheromones added to the bait to make it more attractive.

The organochlorine compounds used are generally aldrin or chlordane, either blown down the nest entrances as a dust, or poured down as an emulsion, usually in water. Some baits (such as Mirex 450 pellets) which are successful in dry weather tend to disintegrate during rainy weather, unless made water repellant by additives. Baits applied just before the annual nuptial flight are most effective because at that time the population of ants is largest and conrol reduces the spread of new colonies.

Fig. 9.331. Atta spp. (Leaf-cutting Ants); J.M. Cherrett





A. cephalotes workers cutting pieces of leaf

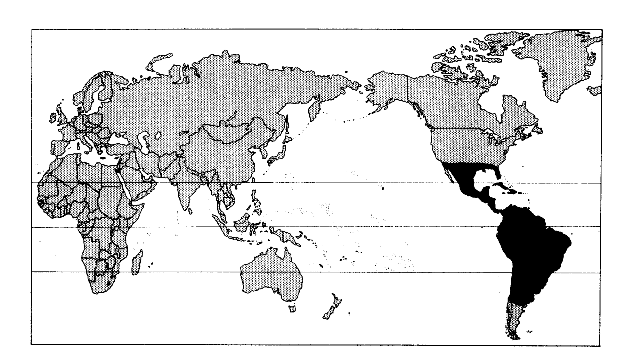


nest site of *A. vollenuxideri* in Paraguay

Acromyrmex spp.

Common name. Leaf-cutting Ants
Family. Formicidae (Attini)
Hosts (main). *Citrus*, cocoa, coffee, maize. (alternative). Cotton, cassava, mango, beans, sweet potato, groundnut, banana, pineapple, rice, wheat, many grasses and many wild plants.
Damage. These are general feeders that show some host-specificity as some species prefer monocoty-ledonous plants whereas others prefer dicotyledonous ones. The foraging worker ants cut pieces of living leaf material and carry them back to the nest for construction of fungus gardens. Severe attacks result in total defoliation and the damaged plants usually die.
Pest status. *Acromyrmex* spp. are regarded collectively as serious pests in the tropical Americas from southern USA to Uruguay and Argentina (25 countries in all).
Life history. These ants are also social and live in underground nests, but the nests are small in comparison to those of *Atta* spp., seldom measuring more than a metre in diameter. The life history details and feeding habits are much the same as the species of Atta except that the colony is smaller, shorter lived, and generally more adapted for life in disturbed ground. Colonies are usually found in urban areas or cultivated ground, and less frequently in forest. Foraging generally only occurs up to about 30 m from the nest, but nest density in agricultural areas is usually from 3–60 nests per hectare. *Acromyrmex* species typically produce a large number of small queens, and dispersal flights are seldom more than about 2 km; queens have been recorded living for seven years, and the nuptial/dispersal flights generally take place at the start of the first rains.
Distribution. These ants only occur in the neotropics. The 23 species of *Acromyrmex* are found from southern USA, Mexico, the W. Indies, C. and S. America down to Uruguay and Argentina, in a total of 25 countries. Most countries have only one or a few species of *Acromyrmex*, but Brazil has 18 species, Bolivia has 10, and Argentina has 17 species.

The most important species is *Acromyrmex octospinosus* (Reich.) which occurs in 20 different countries.
Control. For control see *Atta* spp.



Macromischoides aculeatus (Mayr)
(= *Tetramorium aculeatum*)

Common name. Biting Ant
Family. Formicidae
Hosts (main). Coffee bushes, especially *robusta*.
(alternative). Many wild bushes.
Damage. Small papery nests are constructed between the leaves; when the nest is disturbed by movement of the leaves the ants rush forth with great activity.
Pest status. This is an indirect pest only occasionally important. No direct damage is done to the plant, neither do the ants seem to encourage infestations by scales or mealybugs. But workers in the plantation may be severely bitten at times, even to the extent where they refuse to carry on picking or pruning. The wound is a compound one consisting of a bite by the mandibles followed by formic acid injection into it, making it most irritating.
Life history. The adult is a small brown ant, about 5 mm long, found in numbers of up to several hundred in the small nests made between leaves on the coffee bushes. Often additional plant material may be incorporated into the nest.

The adults are characterized by having two sharp, posteriorly pointing spines at the back of the thorax.

The immature stages are confined solely to the nest and are of no direct importance as pests.
Distribution. Africa only; Zaïre, Uganda, and Tanzania.
Control. Sprays of malathion and dieldrin, as two foliar applications at a 14-day interval, gave almost 70% control of this pest in Uganda.

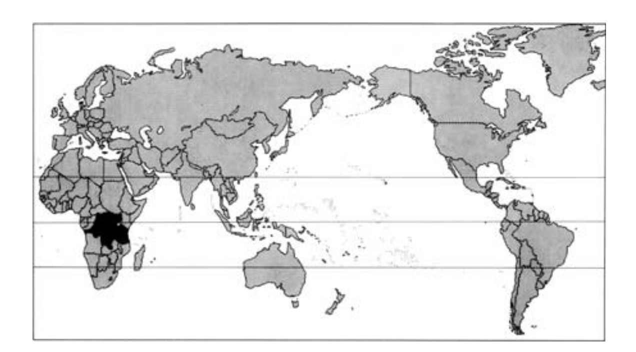
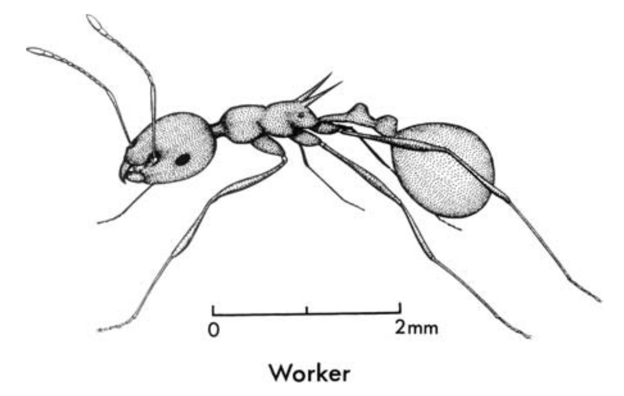


Fig. 9.332. *Macromischoides aculeatus* (Biting Ant); Uganda.





Messor barbarus L.

Common name. Harvester Ant
Family. Formicidae
Hosts (main). Grasses of many species.
(alternative). They also damage cereals and rob seed beds.
Damage. These ants remove grass plants, and cereal plants, from around their nests so the vicinity of the nest is quite bare. Through the use of tracks 5–8 cm wide the ants may forage at distances of 30–50 m or more from their nest, causing areas of severe defoliation.
Pest status. Harvester Ant occurs throughout the drier parts of E. Africa and in places can be serious pests of grassland. Ten or 12 nests commonly occur per hectare and it is not uncommon to find a loss of grazing of the magnitude of 10–20% in some areas.
Life history. The adults are reddish-brown ants with the characteristic narrow petiole (waist) connecting thorax and gaster. The nests are readily recognized by the bare circular areas on the ground surface from which vegetation has been removed. These areas are often slightly depressed and contain up to six slightly raised conical mounds in which are the entrances to the underground nests. There are no ventilator shafts to these nests, such as are produced in termite nests. Seeds are stored underground, often in considerable quantities, and so starving the colony out by a band of insecticide is not often successful.
Distribution. E. Africa.
Control. One successful method used has been to use a bait of aldrin in maize posho; the bait was placed in and around the nest entrances and was carried down into the nests by the workers. Some ants probably died as a result of ingesting the poison and others probably because of the fumigant action.

It is recommended that treated nests be inspected after a month and if required, to repeat the treatment.

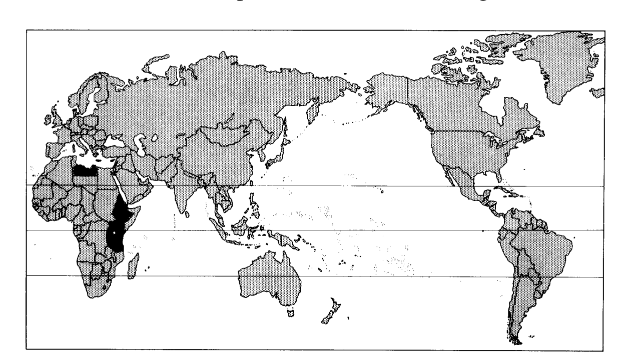
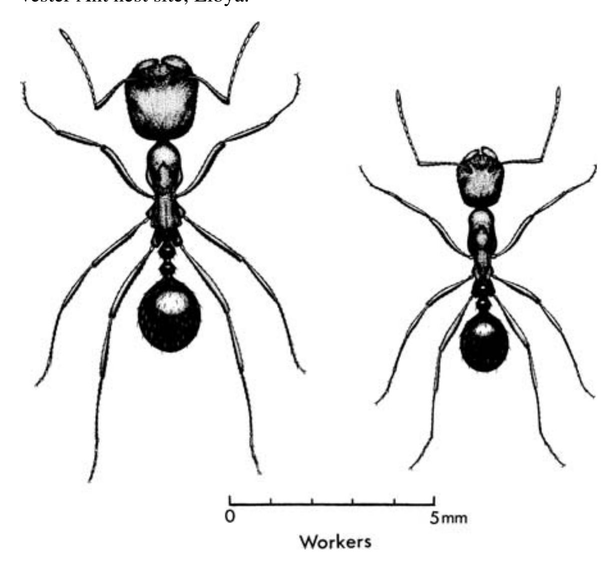
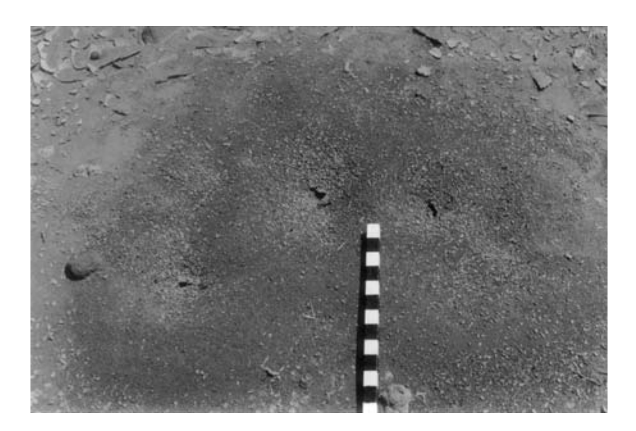


Fig. 9.333. (a) *Messor barbarus* (Harvester Ant); Kenya, (b) Harvester Ant nest site; Libya.





Oecophylla spp.
longinoda (Latr.)
smaragdina (F.)

Common name. Red Tree Ants (Tailor Ants)
Family. Formicidae
Hosts. Any plantation or orchard crop.
Damage. Nests are constructed by sewing leaves together using silken threads so that the nest is a mixture of silk, living and dead leaves. These ants are almost entirely aerial, and respond to vibration of the nest by furious activity and field workers attacked.
Pest status. An indirect pest only occasionally important when it attacks field workers. On the other hand, this ant does kill arboreal insects in the trees it inhabits and so has a definite beneficial effect; it is basically a carnivorous ant.
Life history. An arboreal ant, seldom seen on the ground, living in aerial nests constructed between leaves amongst the twigs of the tree. The main nest is usually large, up to 20 cm diameter or more, and there will be smaller, subsidiary nests in different parts of the same tree or in adjacent trees. The silk used to sew the leaves together is apparently produced by the larvae which are held in the mandibles of the worker ants and used rather like shuttles. There may be several thousand ants in one nest system. They are adept at using telephone wires and cables as a means of aerial translocation. Most nests last for a year or two in the same location.
Distribution. *O. smaragdina* occurs throughout S.E. Asia, from India to S. China and Australia. The closely related *O. longinoda* (Latr.) is found throughout tropical Africa.
Control. In some situations the predation of crop pests by these ants outweighs their pest value, but occasionally they have to be controlled. Sometimes the nest branch can be cut and the entire nest removed, otherwise sprays of dieldrin, or malathion, at a two week interval should be effective.

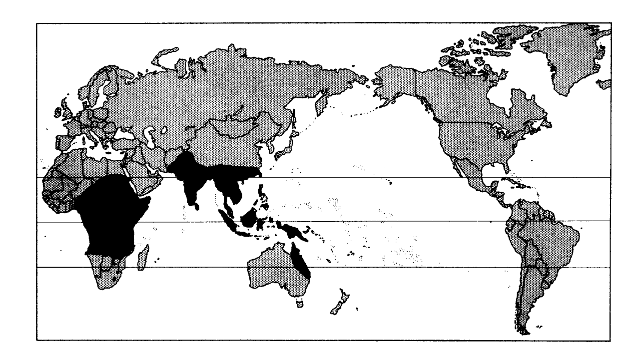


Fig. 9.334. Oecophylla smaragdina (Red Tree Ant); Sarawak.



Solenopsis geminata (F.)

Common name. Fire Ant
Family. Formicidae
Hosts (main). *Citrus* spp., avocado.

(alternative). Coffee, cocoa, and other fruit trees. Seeds and seedlings, notably tobacco, can be destroyed.

Damage. The fruit trees are damaged by girdling, where the ants bite through the bark. Branches, shoots, buds, flowers, and fruit can be injured by small gnawing marks. The ants lick the exuding sap. The ants are very aggressive and their bite is painful.

Pest status. A minor pest of various fruit trees, but of considerable importance as a hazard and deterrent to field workers in areas where it is abundant.

Life history. The ants live in nest burrows in the soil around the base of the tree trunk and make earth galleries on the tree where the bark is gnawed off. They also attend various aphid species on the trees concerned. Nest mound can be 1ft high.

The adults are dark reddish-brown ants; the winged females measure about 5 mm, the small-headed workers about 3 mm, and the large-headed workers (soldiers) 5–6 mm long.

Distribution. W. Africa, Mauritius, India, Bangladesh, Sri Lanka, S.E. Asia, parts of China, Philippines, Indonesia, Papua New Guinea, West Irian, N. Australia, Hawaii, Samoa, and various Pacific islands, S. USA, C. America, W. Indies and the northern half of S. America (CIE map no. A95).

A closely related species is *S. saevissima* (F. Smith) the ‘Imported Fire Ant’ of the S. USA and S. America.

In Mexico and the USA *S. geminata* is reported to be an important predator of insects in lowland annual crops. But they do destroy beneficial predatory insects, and they carry weed seeds back to their nests.

Control. Control can be achieved by the application of contact insecticides in powder or spray form to both nests and entrances, and the foliage of the trees. The insecticides recommended are dieldrin, γ-BHC, diazinon, and heptachlor.

In S. USA millions of acres are sprayed to control this pest and causes considerable ecological damage.

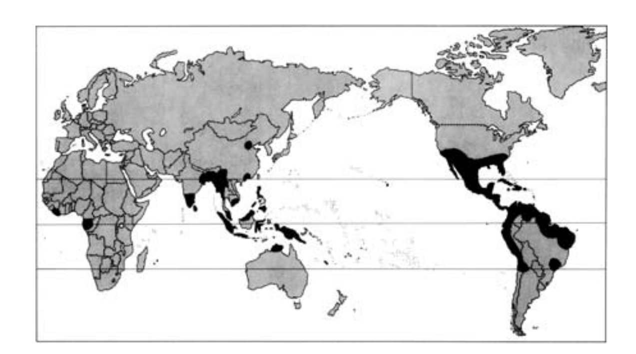
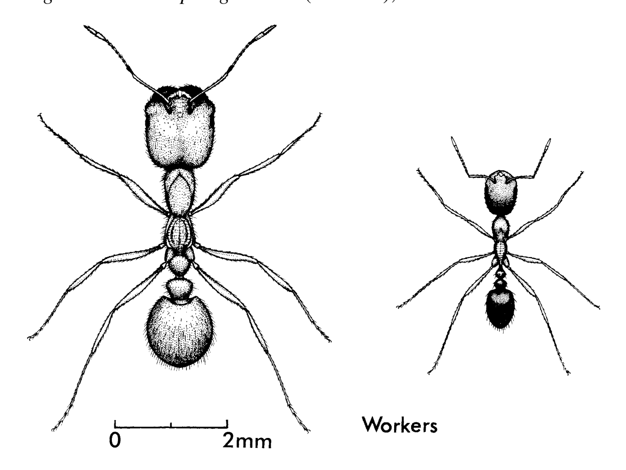


Fig. 9.335. Solenopsis geminata (Fire Ant); S. China.



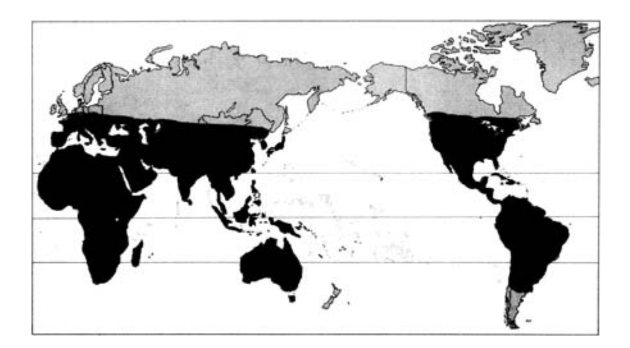
Polistes spp.

Common name. Paper Wasps
Family. Vespidae (Polistinae)
Hosts and Damage. These wasps make nests in bushes and small trees, and if disturbed will attack and sting with vigour. The author was once stung 38 times by two wasps from an accidentally disturbed nest in the Seychelles. The adults are attracted to ripe fruits and will damage them by feeding.
Pest status. An occasional indirect pest when they nest in the foliage of plantation or orchard crops. The adults are also beneficial in that they are carnivorous and prey on many insects that are crop pests. The photograph illustrates a *Polistes* wasp eating the remains of a *Papilio* pupa on a *Citrus* bush.
Life history. A social wasp that occurs as several dozen species throughout the tropics and subtropics; most species bear a strong resemblance to each other, and only differ in minor characters.

The nest is open and small, with only 100–300 cells, and hangs free in vegetation (usually bushes or small trees) from a median pedicel. Some species have the nest flat and plate-like, suspended horizontally, whereas others (as illustrated) have the nest hanging laterally and twisted, with the pedicel at the top edge.

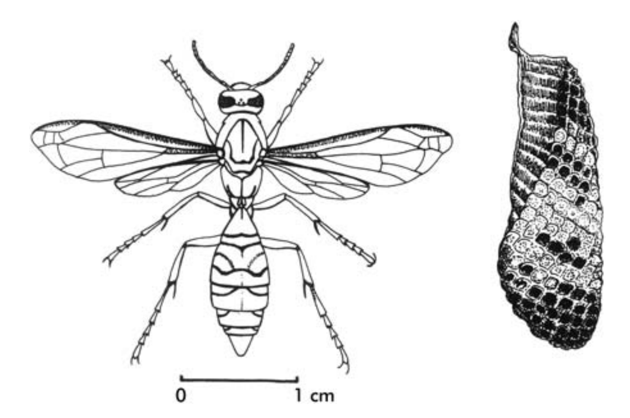
As with all social wasp nests, the colony is annual, and any one nest only lasts for one season, which is inevitably less than one year.

Distribution. The 150 species that occur world-wide are found throughout the tropics and subtropics, and into southern Europe and Canada.



Control. Since these are an integral part of the local insect predator community, making a contribution to the natural control of various pests, it would be preferable for their nests to be left alone. However, there are occasions when a particular nest has to be destroyed because of its location; then a contact insecticide with a rapid knockdown effect is required. Domestic aerosols based upon synthetic pyrethroids are quite effective.

Fig. 9. 336. Polistes spp. (a) paper wasp Polistes olivaceous. (b) paper wasp eating Papilio pupa on Citrus bush.





paper wasp eating *Papilio* pupa on *Citrus* bush

Vespa/Vespula spp.

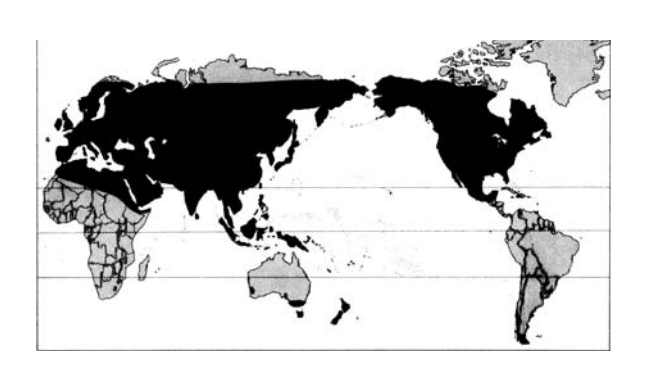
Common name. Common Wasps
Family. Vespidae
Hosts and Damage. These social wasps build nests in the ground, in hollow trees, in buildings and in some cases in a large subspherical papery structure hanging free from a pedicel in the foliage of trees. Nests in, or in the vicinity of, plantation crops or orchards may be disturbed by field workers who then will probably be attacked by the wasps and stung. The adults are attracted by ripe fruits (as are *Polistes*) and they will damage ripe fruits in order to feed on the sugary sap; the fruits usually attacked include papaya, mango, guava, grape, peach, apple, pear, plum, strawberry, and sometimes *Citrus*.
Pest status. An indirect pest when they nest in plantation crops or near human dwellings, having a painful sting and aggressive nature. Also a beneficial insect in that they are predators and will undoubtedly be feeding upon some insects that are crop pests. In all parts of the world adult wasps are attracted to ripe fruits and will damage soft-skinned fruits that are left on the tree after ripening.
Distribution. The 50 species of *Vespa* and *Vespula* are collectively completely cosmopolitan, and one or two species are very widely distributed.
Life history. The genera *Vespa* and *Vespula* include some 50 species on a worldwide basis, most of which resemble each other quite closely in morphology and life history.

The nest is usually large, sometimes built underground, sometimes in a hollow tree, often in buildings and dwelling places, and also hanging free from a tree. The free nest is either spherical or elongate, measuring from 20–30 cm in diameter and 20–40 cm in length, and hangs from a single thick pedicel attached to a branch. The nest is constructed from chewed tree bark and wood fragments mixed with saliva and has a papery appearance. The entrance holes are at the base, and internally the nest consists of several layers of cells, or combs, each cell being the home for a single larva. The larvae are fed on chewed insect remains and sometimes honey-dew or sugar obtained from ripe fruits. The entire larval and pupal development takes place within the cells of the nest combs. The largest nests will contain several thousand individuals.

The colony only lives for one season, even in the tropics, and at the end of the season (usually autumn) young queens emerge and fly off to hibernate until the following spring when they start to build a nest of their own. The old nest disintegrates in the winter storms.
Control. When control is needed there are various different approaches, as follows:
(a) direct nest destruction by physical means.
(b) nest poisoning, either by direct insecticide application to the nest entrance, or the use of poison baits of sugar or syrup with a slow-acting insecticide added, so that the bait is carried back to the nest.
(c) destruction of foraging workers using traps of different types; various synthetic attractants are now commercially available, including leptyl butyrate.

Against flying wasps a contact insecticide with good knockdown effect should be used, and the spray operator should wear full protective clothing.

The chemicals regarded as effective against wasps include dieldrin, chlordane, iodofenphos, diazinon and fenitrothion, the latter two being also available in an encapsulated form for slow release.



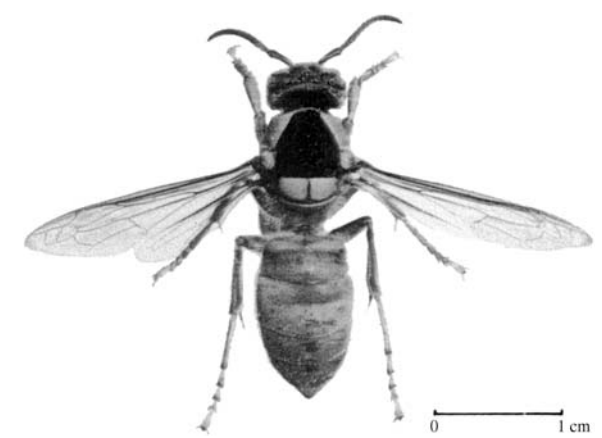
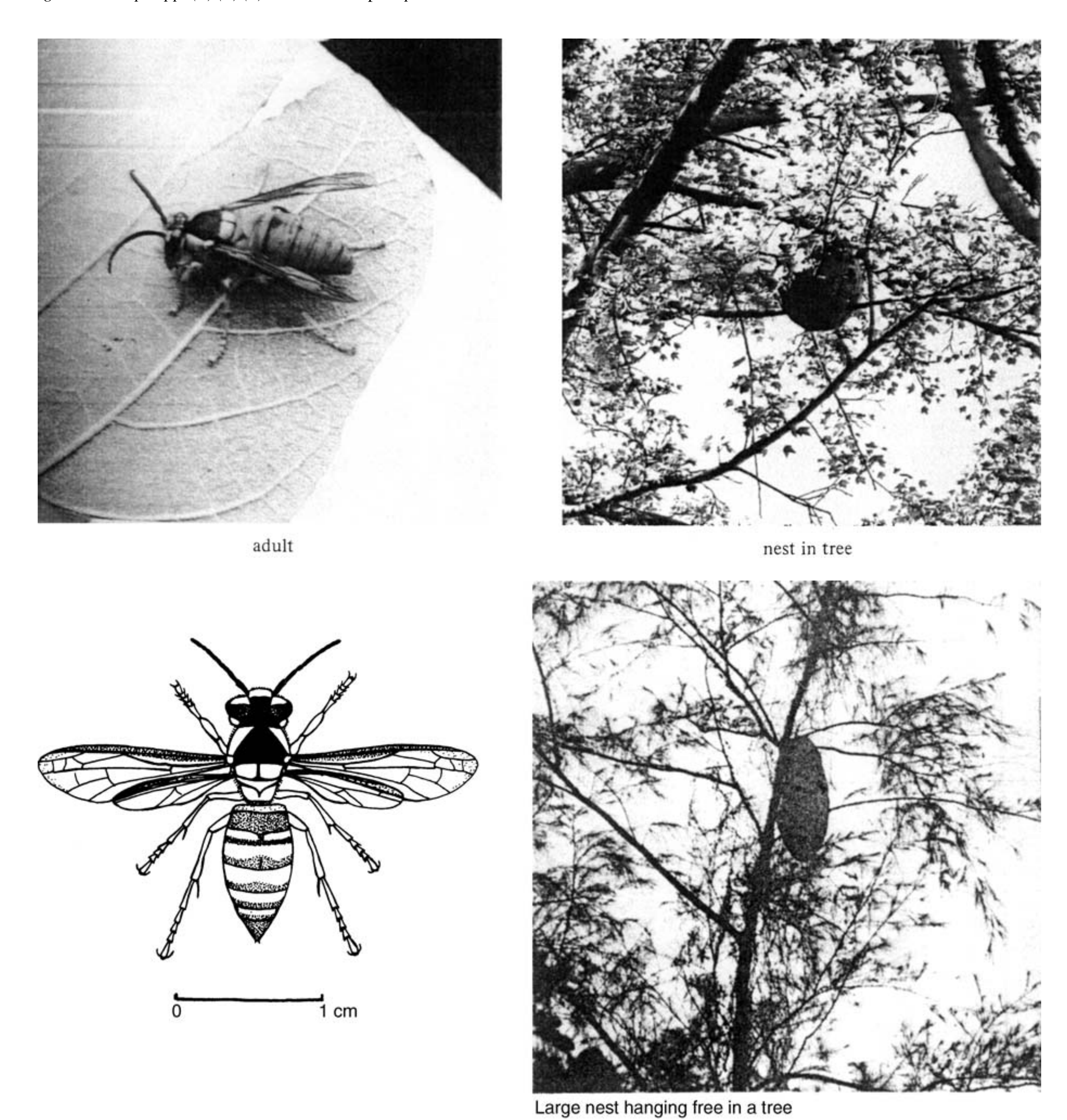


Fig. 9.337. Vespa spp. (a) (b) (c) Common wasp *Vespa bicolor*.



Class **ARACHNIDA**

Order **ACARINA**

These arthropods belong to a separate class from the Insecta called the Arachnida. They are characterized by having four pairs of legs in the adult stage. The body is divided into proterosoma (gnathosoma and propodosoma) and hysterosoma, instead of head, thorax and abdomen. The first stage in the life-cycle is a six-legged larva which on moulting becomes an eight-legged nymph.

Family **Tetranychidae**

(Spider Mites) Sometimes referred to as the Red Spider Mites because many of the species are bright red in colour; others are green or orange. They are all plant feeders and resemble small, reddish spiders. The eggs are relatively very large, often red, globular and scattered singly over the leaf surface. They are of moderate size (for mites), being about 0.8 mm long, with a soft integument without skeletal plates, and there is a pair of eyes on either side of the propodosoma. There are many important pest species both in the tropics and temperate regions. Attacked plants are often covered with an extensive fine webbing.

Family **Tenuipalpidae** (= Phytoptipalpidae)

Very small, reddish mites (0.2–0.3 mm long), which feed on plants. A suture separating the propodosoma from the hysterosoma may or may not be present. Body form varies somewhat within this group. The adults usually have four pairs of legs but some genera only have three pairs.

Family **Tarsonemidae**

Tarsonemids have a segmented body and an anterior dorsal shield which lacks a roof-like projection. They are placed in the suborder Trombidiformes, in part because of their anatomical degeneration. Heteromorphic males occur in this family. They have a simplified life-cycle in which the nymphal stage is quiescent; the active feeding larva transfers through the quiescent nymphal stage into a mature adult. There are several important polyphagous pest species.

Family **Eriophyidae**

(Gall Mites) These mites are also in the suborder Trombidiformes; they are minute in size, rather worm-like, and possess only two pairs of anterior legs. The propodosoma is shield-like and has distinctive specific patterns; the hysterosoma is elongated and annulate. As a group these mites are either free-living on plants or gall makers; amongst the galls they produce are the characteristic 'erinia' on the undersurface of leaves. These moss-like outgrowths are induced by the mites which then inhabit them.

Phytophagous mites (Class Arachnida; Order Acarina)

Mites are obviously not insects, but the phytophagous species are invariably regarded as the purview of the agricultural entomologist, together with a few other arthropods. Mites (Order Acarina) are mostly small to tiny (1.0–0.1 mm) in size; typically they have a 'head' region (gnathosoma), with a large undivided posterior region (idiosoma). As typical arachnids, they have four pairs of walking legs; usually two pairs directed anteriorly and two backwards. However, the larva that hatches from the egg has only three pairs of legs; after the first moult into the nymphal stage it acquires the extra pair. In some families there has been body modification with the loss of legs; the Eriophyidae (gall mites) mostly have only the anterior two pairs of legs, and these are reduced in size, and in many species the body is elongated and worm-like.

In some respects it is difficult to generalize about the order as there are several quite different families (of phytophagous mites) with major differences in their biology, but in the present work there is insufficient space available to permit a more detailed treatment.

The phytophagous mites feed on sap, obtained by piercing the epidermal cells with the chelicerae that are modified into stylets. When epidermal cells are emptied of sap, the air that enters inside gives the leaf surface a silvery appearance (often referred to as scarified) which is typical of much mite damage (and also some thrips damage). When epidermal damage is extensive then the leaf suffers dehydration followed by desiccation and bronzing; severely bronzed leaves usually fall prematurely. The spider mites (Tetranychidae) typically produce leaf scarification (and bronzing) as their main damage symptom, sometimes accompanied by extensive foliage webbing with silk. Tarsonemidae and some other mites usually attack young leaves, buds and shoots, and their feeding causes growth deformation. The Eriophyidae, commonly called gall, rust, or blister mites, live in a far closer association with the host plant and they cause foliage distortion which provides a favourable microenvironment for their dwelling. Their infestation of young leaves results in leaf folding, leaf rolling, cupping, and the formation of erinea, and the tiny worm-like mites live within the proliferated epidermal tissues in a very sheltered microhabitat.

Most of the phytophagous species are quite host-specific, either to a genus or a family of plants; this is especially true of the Eriophyidae as their host plant relationship is more intimate than the others. However, a few species of spider mites are quite polyphagous and they are recorded from a very wide range of hosts, which accounts in part for their importance as crop pests. Some mites are fungivorous and others feed on decaying plant material, and the examination of a mite-damaged plant may be very confusing in that there may be several other species present that are not primary pests. There will also usually be predacious mites present, but these are usually distinguishable by their larger size and active nature (they often have longer legs). In the 'big-bud' condition induced on some plants by eriophyid mites there are usually some inquiline species present within the swollen bud. Many plant species are in fact attacked by a large number of different mites, in several different ways, in different parts of their distributional range, but some infestations are overlooked because of the tiny size of the mites and obscure symptoms; for example, the walnut group is recorded as host for about ten different phytophagous mite species worldwide. But for plant protection purposes we tend to concentrate on a relatively small number of mite species per crop plant, and in point of fact on some crops the mite pests are ignored completely in most literature.

One aspect of mite biology of importance in relation to their status as crop pests is their ability to survive periods of inclement weather in a state of diapause or aestivation. Diapause proper (i.e. overwinter) is practised by mature females and also as overwintering eggs. Aestivation is regularly encountered in warmer parts of the world, sometimes in the egg stage, but in the Eriophyidae by adult females only as these mites do not normally lay resistant eggs. Eggs of spider mites are typically laid on the leaves (except for overwintering temperate eggs) and most are large, red and globular and easily recognized through a hand lens; but the winter eggs of temperate species are laid on the spurs and woody twigs. Eggs of Eriophyidae are so minute that they are seldom seen in the field.

Field infestations are usually preyed upon heavily by predacious mites, various predacious bugs and a few Coccinellidae, and most pest populations are to some extent always controlled by these natural enemies. There have been many recorded cases where careless pesticide use has destroyed the natural enemies rather than the pests and has resulted in dramatic pest resurgences. The importance of mite predators can easily be seen through the present practice of commercially controlling red spider mites (*Tetranychus* spp.) in glasshouses using the predatory *Phytoseilus riegeli*. The family Phytoseiidae contains the most important species of predacious mites, and these mostly belong to the genera *Amblyseius, Phytoseilus* and *Typhlodromus*.

Resistance to acaricides is now very widespread for many species, especially the genera *Panonychus* and *Tetranychus* (Tetranychidae). The most striking aspect of this phenomenon has been the demonstration that some species of *Panonychus* actually thrived on a diet supplemented with DDT!

Some species of mites are agriculturally important in that they are known vectors of various virus diseases; for example *Eriophyes tulipae* carries three different wheat viruses, and *Cecidophyopsis ribis* carries the virus for black currant reversion disease. Some other species of mites regularly carry fungal spores on their bodies and thus are responsible for the spread of some fungal diseases.

The earlier use of the name *Tetranychus telarius* (L.) has been discontinued since it was established that it

included two very closely related, but different species: *T. cinnabarinus* is the pantropical species (with red-coloured summer female), and *T. urticae* is the cosmopolitan temperate species (with green summer female); 'winter' females of both species are green and scarcely distinguishable.

Control of phytophagous mites

As already mentioned, the existing natural control through predacious mites and insects is usually important and care must be taken to ensure its continuation. The biological control of *T. urticae* in glasshouses in Europe and N. America using the predatory mite *Phytoseilus riegeli* is now a regular commercial practice and generally successful; the predator is available from commercial breeders. Release of predatory mites (and insects) is sometimes practised on field crops in the tropics, but usually only limited control is achieved.

Acaricides The earliest compound used for mite control was sulphur, and in fact this is still widely used. But susceptibility to sulphur varies somewhat; the Eriophyidae and Tenuipalidae are generally susceptible, but most spider mites are not. A complication is that some plants are sensitive to sulphur, and this phytotoxicity restricts the use of this chemical; these plants are sometimes referred to as 'sulphur-shy'.

The next effective compounds were the dormant sprays of tar oils, and they successfully killed the overwintering eggs of temperate spider mites. Now the recently developed refined 'summer oils' can be used on actual foliage for killing the active stages of the mites. The use of oils against mites has continued, despite the recent development of new acaricides, because there seems to be no development of resistance against these oils.

The range of pesticides effective against phytophagous mites is now very extensive and includes the following widely used chemicals.

sulphur	dicofol
tar oils	dimethoate
petroleum oils	disulfoton
DNOC	endosulfan
aldicarb	malathion
amitraz	oxydemeton-methyl
azinphos-methyl	pirimiphos-methyl
chlorpyrifos	quinomethionate
cyhexatin	tetradifon
derris	thiometon
demeton-*S*-methyl	triazophos
	vamidothion

They are usually employed in high-volume sprays, but other methods of application are also used, depending in part on the nature of the chemical being used. Some of these chemicals are more effective than others against a particular mite (some do not kill the eggs or hibernating females) and some acaricides are not recommended for use on certain crops, so local advice should always be sought for recommendations applicable to a particular pest/crop situation.

Important mite pests of agricultural crops

The total number of recorded mite pests attacking growing and stored crops is very large, as can be seen by reference to Jeppson, Keifer & Baker (1975); some of the more important species are listed here:

Tarsonemidae

Polyphagotarsonemus latus (Banks) – (Broad Mite) polyphagous; cosmopolitan (CIE map no. A.191).
Stenotarsonemus ananas (Tryon) – (Pineapple Tarsonemid) Australia, Hawaii.
Stenotarsonemus bancrofti (Mich.) – (Sugarcane Stalk Mite) Africa, S.E. Asia, N., C. and S. America.
Stenotarsonemus laticeps (Halb.) – (Bulb Scale Mite) Europe, USA.
Stenotarsonemus spirifex (Marchal) – (Oat Spiral Mite) Europe.
Tarsonemus pallidus Banks – (Strawberry (Cyclamen) Mite) Europe, Japan, USA (now regarded as two distinct races – see below).
Tarsonemus pallidus fragariae Zimm. – (Strawberry Mite),
Tarsonemus p. pallidus Banks – (Cyclamen Mite).

Tenuipalpidae (false spider mites)

Brevipalpus californicus (Banks) – (Scarlet Tea Mite) cosmopolitan (CIE map no. A. 107).
Brevipalpus lewisi (McG.) – (Citrus Flat Mite) polyphagous; Near East, Australia, USA.
Brevipalpus obovatus Donn. – (Privet Mite) polyphagous; cosmopolitan (CIE map no. A. 128).
Brevipalpus phoenicis (Geijskes) – (Red Crevice Tea Mite) polyphagous; cosmopolitan (CIE map no. A. 106).
Cenopalpus spp. – on many fruit trees and other plants; Europe, W. and S. Asia.
Dolichotetranychus floridanus (Banks) – (Pineapple False Spider Mite) S.E. Asia, Japan, USA, C. America.
Raoiella indica Hirst. – (Date Palm Scarlet Mite) Egypt, India, S.E. Asia, C. America (CIE map no. A.210).
Tenuipalpus zhizhilashviliae Peck – (Persimmon False Spider Mite) Japan.

Penthaleidae

Halotydeus destructor (Tucker)–(Red-legged Earth Mite) Cyprus, S. Africa, New Zealand, Australia (CIE map no. A. 119).
Penthaleus major Duges – (Winter Grain Mite) cosmopolitan.
Siteroptes cerealium (Kirch.) – (Grass and Cereal Mite) Europe.

Acaridae

Acarus siro L. – (Flour Mite) cosmopolitan.
Rhizoglyphus echinopus F.et R. – (Bulb Mite) Europe, Japan, USA.
Tryophagus spp. – grasses and cereals; cosmopolitan.

Tetranychidae (spider mites)

Bryobia cristata Duges – (Grass-Pear Bryobia Mite) Europe, N. Africa, Japan, Australasia.

Bryobia eharai P.et K. – (Chrysanthemum Spider Mite) Japan, Pakistan.
Bryobia graminum Schrank – (Grass Bryobia Mite) Europe.
Bryobia kissophila Eynd. – (Ivy (Clover) Bryobia Mite) Europe.
Bryobia praetiosa Koch – (Clover Mite) Europe, Asia, Africa, Australia, N. and S. America.
Bryobia ribis Thom. – (Gooseberry Bryobia Mite) Europe.
Bryobia rubrioculus (Sch.) – (Apple and Pear Bryobia (Brown) Mite) Europe, Asia, Japan, S. Africa, Australia, N. and S. America.
Eotetranychus boreus Ehara – (Apricot Spider Mite) Japan, USA.
Eotetranychus hicoriae (McG.) – (Pecan Leaf Scorch Mite) USA.
Eotetranychus pruni Oud. – (Chestnut Spider Mite) Europe, Asia, Japan, USA.
Eotetranychus sexmaculatus Riley – (Six-spotted Spider Mite) Japan, China, India, New Zealand, USA.
Eotetranychus uncatus Garman – (Walnut Spider Mite) Japan, USA.
Eutetranychus banksi (McG.) – (Texas Citrus Mite) USA.
Eutetranychus orientalis (Klein) – (Oriental Mite) Africa, Asia, USA.
Eutetranychus spp. – fruit trees; Africa, India.
Oligonychus afrasiaticus (McG.) – (Date Spider Mite) Africa, Near East.
Oligonychus coffeae (Niet.) – (Red Coffee (Tea) Mite) pantropical (CIE map no. A. 165).
Oligonychus indicus (Hirst) – (Sugarcane Leaf Mite) India, USA.
Oligonychus mangiferus (R. & S.) – (Mango Spider Mite) Africa, India, USA, S. America (CIE map no. A.209).
Oligonychus orthius Rim. – (Sugarcane Spider Mite) Japan.
Oligonychus pratensis (Banks) – (Banks Grass Mite) Africa, USA, C. and S. America.
Oligonychus punicae (Hirst) – (Avocado Brown Mite) India, USA, C. and S. America.
Oligonychus shinkajii Ehara – (Rice Spider Mite) Japan.
Oligonychus yothersi (McG.)–(Avocado Red Mite) USA, C. and S. America.
Panonychus citri McG. – (Citrus Red Spider Mite) cosmopolitan (CIE map no. A. 192).
Panonychus ulmi Koch – (Fruit Tree Red Spider Mite) cosmopolitan (CIE map no. A.31).
Petrobia harti (Ew.) – (Oxalis Spider Mite) cosmopolitan.
Petrobia latens Muller – (Brown Wheat Mite) India, Japan, USA.
Schizotetranychus asparagi (Oud). – (Asparagus Spider Mite) Europe, USA, Hawaii.
Schizotetranychus celarius (Banks) – (Bamboo Spider Mite) China, Japan, USA.
Schizotetranychus spp. – (Citrus Spider Mites) India.
Tetranychus canadensis (McG.) – (Four-spotted Spider Mite) USA, Canada.
Tetranychus cinnabarinus Bois. – (Carmine Spider Mite) pantropical.
Tetranychus ludeni Zacher – polyphagous; worldwide.
Tetranychus marianae McG. – (Solanum Spider Mite) S.E. Asia, Australia, USA, C. and S. America (CIE map no. A.403).
Tetranychus mcdanieli (McG.) – (McDaniel Spider Mite) Canada, USA.
Tetranychus neocaledonicus Andre – (Vegetable Spider Mite) pantropical.
Tetranychus turkestani V. & N. – (Strawberry Spider Mite) Europe, Asia, USA.
Tetranychus urticae Koch – (Two-spotted Spider Mite) cosmopolitan (temperate).
Tetranychus spp. (many) – (Spider Mites) many hosts; worldwide.

Eriophyidae (gall/blister/rust mites)
Abacarus hystrix (Nalepa) – (Grain Rust Mite) Europe, Asia, Canada, USA.
Acalitus essigi (Hassan) – (Redberry Mite) UK, New Zealand, USA.
Acalitus gossypii (Banks)–(Cotton Blister Mite) USA, C. and S. America.
Acalitus phloeocoptes (Nalepa) – (Almond and Plum Bud Gall Mite) Europe, Asia Minor, USA.
Acalitus vaccinii (Keiffer) – (Blueberry Bud Mite) USA.
Acaphylla theae Watt. – (Pink Tea Rust Mite) India, China, Japan.
Aceria sheldoni (Ewing)–(Citrus Bud Mite) cosmopolitan (CIE map no. A. 127).
Aceria spp. (5) – fruit trees; India, S. America.
Aculops lycopersici (Massee) – (Tomato Russet Mite) worldwide (CIE map no. A. 164).
Aculops pelekassi Keifer – (Pink Citrus Rust Mite) Japan.
Aculus cornutus (Banks) – (Peach Silver Mite) Europe, Asia, N., C. and S. America.
Aculus fockeui (N. & T.) – (Plum Rust Mite) Europe, Canada, USA.
Aculus schlechtendali (Nalepa) – (Apple Rust Mite) Europe, Asia, Canada, USA.
Calacarus carinatus (Green) – (Purple Tea Mite) Asia, Japan, Australasia, USA (CIE map no. A.324).
Calepitrimerus vitis (Nalepa) – (Grape Rust Mite) Japan.
Cecidophyopsis ribis (West.) – (Currant Bud Mite) Europe, Canada, USA (CIE map no. A. 129).
Colomerus vitis Pag. – (Grape Gall Mite) worldwide.
Diptacus gigantorhynchus (Nalepa) – (Big-beaked Plum Mite) cosmopolitan.
Epitrimerus pyri Nalepa – (Pear Rust Mite) Japan, Canada, USA.
Eriophyes caryae Keiffer – (Pecan Leaf-roll Mite) USA.
Eriophyes erineus (Nalepa) – (Persian Walnut Blister Mite) Asia, USA.
Eriophyes ficus Cotte – (Fig Mite) USA
Eriophyes litchi Keiffer – (Litchi Mite) Hawaii, Pakistan.

Eriophyes lycopersici (Wolf.) – (Tomato Erineum Mite) pantropical.
Eriophyes mangiferae (Sayed) – (Mango Bud Mite) Near East, S. Asia, USA.
Eriophyes oleae Nalepa –(Olive Bud Mite) Mediterranean Region.
Eriophyes pyri (Pgst.) – (Pear Leaf Blister Mite) Europe, India, Canada.
Eriophyes rossettonis (Keifer) – (Cashew Bud Mite) S. America.
Eriophyes sheldoni Ewing – (Citrus Bud Mite) cosmopolitan (CIE map no. A. 127).
Eriophyes tristriatus (Nalepa) – (Walnut Leaf Gall Mite) Europe, parts of Asia.
Eriophyes tulipae Keifer – (Wheat Curl Mite) Europe, Asia, N. Africa, Australasia, USA.
Eriophyes spp. – fruit trees and shrubs; worldwide.
Eriophyes spp. – grasses, cereals and sugarcane; worldwide.
Phyllocoptella avellaneae (Nalepa) – (Filbert Big Bud Mite) Europe, Asia, Australia, Canada, USA.
Phyllocoptes gracilis (Nalepa) – (Dryberry (Blackberry Leaf) Mite) Europe, USA, Canada.
Phyllocoptruta oleivora (Ash.) – (Citrus Rust Mite) pantropical (CIE map no. A.78).
Phytoptus pyri Pgst. – (Pear Leaf Blister Mite) Asia, S. Africa, USA.

Eutetranychus orientalis (Klein)

Common name. Oriental Mite
Family. Tetranychidae
Hosts (main). *Citrus* spp.

(alternative). A wide range of alternative hosts including castor, cotton, *Ficus, Morus*, cucurbits, frangipani, *Croton*, and *Euphorbia*.

Damage. Upper surfaces of fully expanded leaves turn a yellow or red-brown.

Pest status. A sporadically serious pest of *Citrus*, especially at lower altitudes.

Life history. Eggs, which are subspherical and pale brown, are usually laid along the main veins on the upper surface of the leaves. They are just visible to the unaided eye, being a diameter of 0.14 mm.

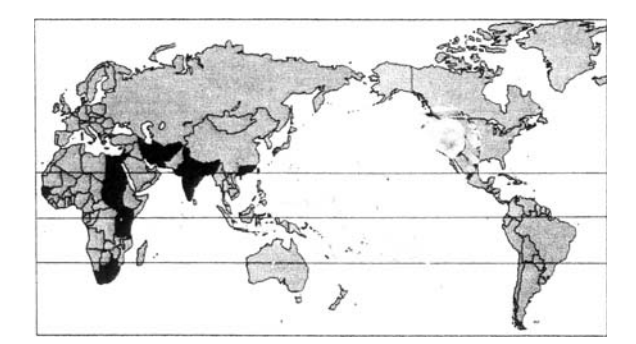
The six-legged larva is brownish.

After a resting phase the nymph emerges from the larval skin. The female mite passes through a second resting stage and second nymphal stage before becoming adult. The male has only one nymphal stage. Nymphs have eight legs and are similar in general form to the adult.

The adult female is round-bodied, brownish and almost 0.5 mm long. It emerges from the second nymphal skin after a third resting period. The male has a more slender and elongate body and is smaller and redder than the female. The females have dorsal striae of the propodosoma more or less parallel, and the lateral setae are moderately slender and spatulate.

All active stages feed and moult on the upper surfaces of fully expanded leaves. The cast skins remain stuck to the leaf surface and appear as small white irregular specks.

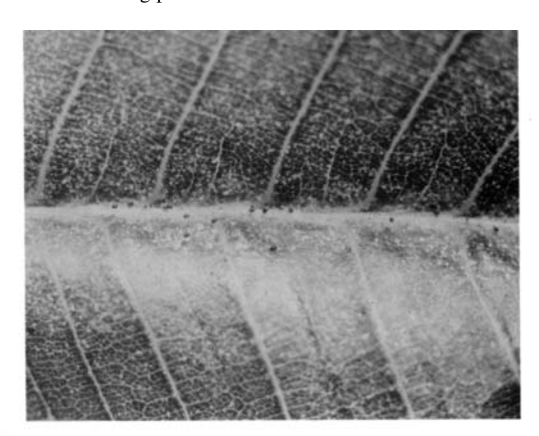
The total life-cycle probably takes between one and three weeks, according to temperature.

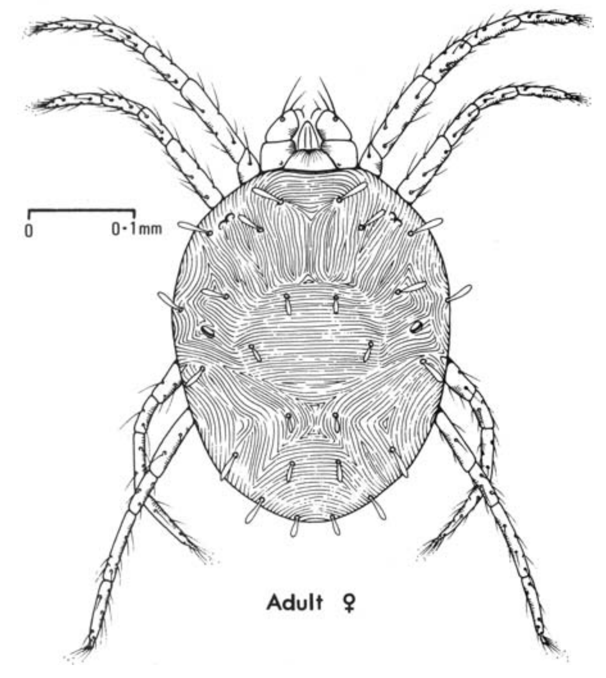


Distribution. Africa (Egypt, Senegal, Aden, E. and S. Africa, Sudan); Cyprus, Jordan, Lebanon, Afghanistan, Israel, Iran, India, Bangladesh and Taiwan.

Control. The recommended control measures are foliar sprays of dicofol or white oil.

Fig. 9.338. Eutetranychus orientalis (Oriental Mite); S. China: adult ♀ and infested frangipani leaf.





Oligonychus coffeae (Nietner)

Common name. Red Coffee Mite (Red Tea Mite)
Family. Tetranychidae
Hosts (main). Tea, and coffee.

(alternative). A wide range of trees and shrubs including castor, and *Grevillea*.

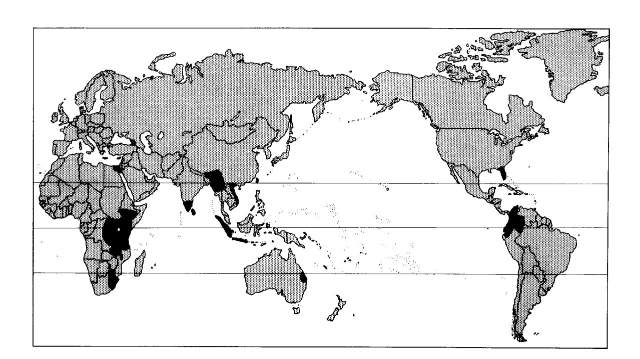
Damage. The upper surface of fully hardened leaves turn a yellowish-brown, rusty or purple colour. If the tea bush is drought-stressed, flush leaves may also be attacked.

Pest status. An occasional pest of tea in many areas; attacks are usually confined to a few bushes. This pest is sometimes called the Red Tea Mite.

Life history. Eggs are laid singly on the upper leaf surfaces, often near a main vein; they are just visible to the unaided eye. They are nearly spherical but have a fine filament projecting on the upper side. They are bright red, changing to orange just before hatching. They hatch after 8–12 days.

The larva is six-legged, almost spherical, orange, and slightly larger than the egg.

There are two nymphal stages; the protonymph and the deutonymph. They are more oval than the larva and have four pairs of legs. The front part of the body is red, the posterior half reddish-brown or purple. The total period spent in the larval and nymphal stages is 9–12 days.



Adults are little less than 0.5 mm, and are similar in coloration to the nymph. Female mites, which are usually more numerous than the males, usually lay 4–6 eggs per day for 2–3 weeks, starting immediately after the final moult.

All active stages feed together on the upper surfaces of the leaves, and the cast skins of the larval and nymphal stages remain stuck on to the leaf and may be seen with the unaided eye as irregular white spots.

This species is scarcely separable from *Tetranychus cinnabarinus* without the use of microscopic taxonomic characters.

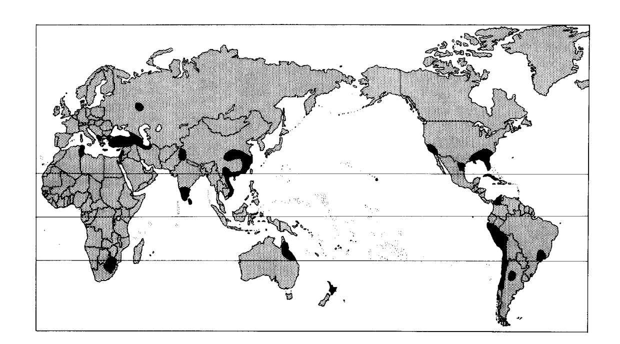
Distribution. Widely scattered records have been made from Africa (Egypt, Ethiopia, E. Africa, Malawi, Zaïre and S. Africa), USSR (Transcaucasia), Asia (S. India, Sri Lanka, Burma, Indo-China, Java, Sumatra, and Taiwan), Australia (Brisbane), USA (Florida), C. America (Costa Rica), and S. America (Colombia, and Ecuador) (CIE map no. A165).

Control. The usual recommendation is to spray the foliage with either dicofol or dimethoate. The other acaricides referred to for control of *T. cinnabarinus* would probably be equally effective against this pest.

Panonychus citri (McG.)

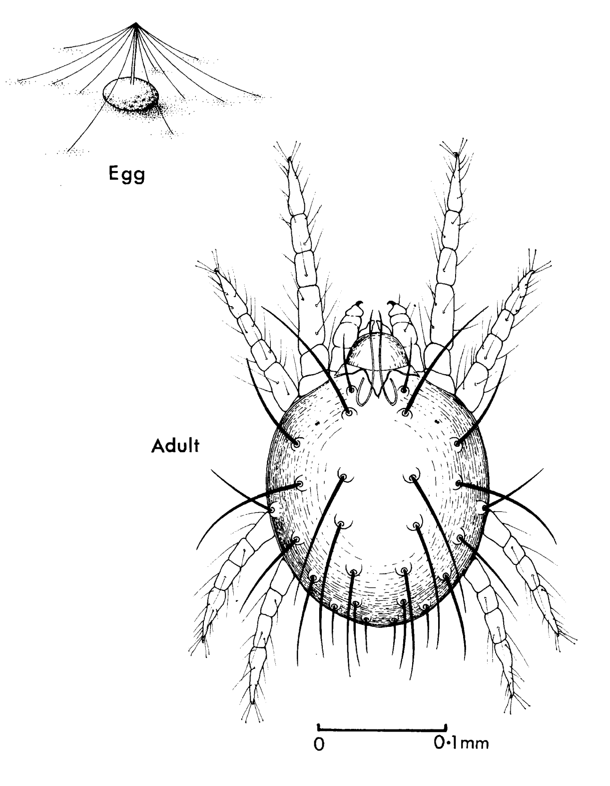
Common name. Citrus Red Spider Mite
Family. Tetranychidae
Hosts (main). *Citrus* spp.
(alternative). Broad-leaved evergreen ornamentals; peach and various deciduous fruits (pear, almond, Rosa).
Damage. Symptoms of attack are silvering of leaves, with severely damaged leaves developing dead areas – the dead leaves sometimes remain on the tree for a long time. Die-back of young twigs may occur and fruits on affected branches may drop.
Pest status. A major pest of *Citrus* in California and Florida especially; damage is most evident on the leaves, and is of little consequence to mature fruit, but severe infestation weakens the trees and may be followed by a poor crop in the next season.
Life history. The egg is minute, bright red, spherical, stalked, and with threads radiating to the leaf surface, which is characteristic of the species. The egg period lasts 6–20 days, according to season.

Both nymphs and adults are dark red, rounded, and have characteristic white setae arising from tubercles on the body. Adult males are about 0.5 mm and females 0.6 mm. The nymphal period lasts 14 days under optimum conditions. A temperature of 25°C and RH of 60–70% favours breeding. Dispersal is mainly by wind, and transportation of infested nursery stock.



Distribution. S. W. Europe, Tunisia, Iran, Turkey, S. Africa, India, Sri Lanka, Vietnam, S. China, Japan, Australia (Queensland), New Zealand, Hawaii, S. USA (California, Florida, etc.), W. Indies, and S. America (Brazil, Argentina, Chile, Peru, and Colombia) (CIE map no. A192).
Control. Control is similar to that for *T. cinnabarinus* (p. 505).

Fig. 9.339. Panonychus citri (Citrus Red Spider Mite); S. China.



Tetranychus cinnabarinus (Boisd.)

(= *T. telarius* (L.) *part*.; etc.)

Common name. Carmine Spider Mite (Tropical Red Spider Mite)

Family. Tetranychidae

Hosts. Polyphagous on low-growing plants throughout the semitropical areas of the world; very frequently on cotton and citrus; in temperate regions mostly confined to glasshouses, on a wide range of crops; 100 + hosts recorded.

Damage. Infested leaves become spotted yellowish, then rust-coloured; finally they wither, die and are shed prematurely. Red or greenish mites are just visible to the unaided eye, underneath the leaves.

Pest status. A widespread and regular pest of many crops in warmer parts of the world and in greenhouses in temperate regions.

Life history. The eggs are spherical, pinkish, about 0.1 mm in diameter; laid singly on the underside of the leaves or stuck to the strands of silk spun by the adult mites. Hatching requires 4–7 days; each female may lay 100–200 eggs over about three weeks.

The tiny six-legged larva is pinkish; after 3–5 days it moults into the first nymphal stage (protonymph), and a few days later into the deuteronymph; total nymphal period is 6–10 days.

The female is red or green in colour, 0.4–0.5 mm long, with several dark body spots. The male is slightly smaller. Both adults spin silken webbing over the host plant foliage. All active stages tend to feed on the underside of the leaves between the main veins. These mites do not hibernate (diapause) but may pass into a state of extended quiescence if the temperature falls. Optimum temperature for development is about 32°C. The life-cycle can be completed in as short a time as 8–12 days, and in warm climates there may be up to 20 generations per year.

Distribution. Recorded throughout much of Africa, southern Europe, southern Asia, Japan, Australia, New Zealand, USA, C. and S. America; farther north in temperate regions usually confined to greenhouses (CIE map no. A.390).

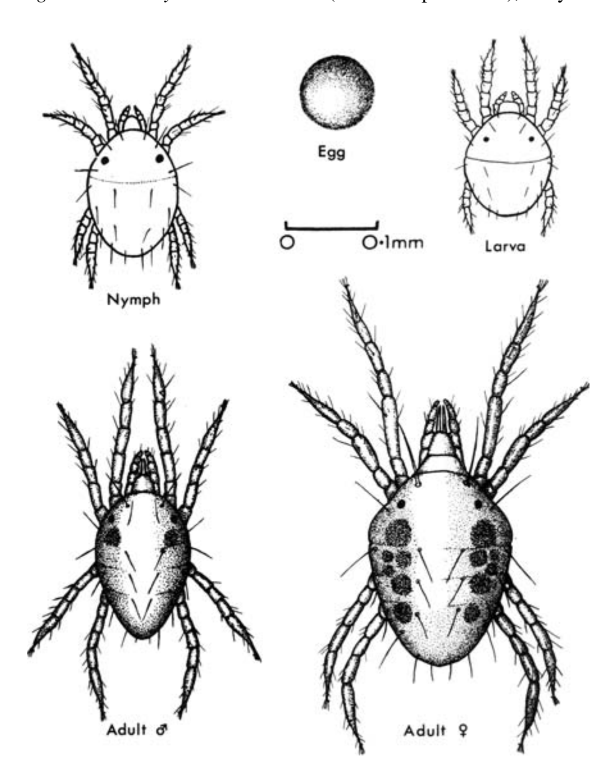
Control. In greenhouses in Europe and USA control is usually achieved using the predacious mite *Phytoseilus riegeli*. Many greenhouse infestations are often a mixture of this species together with *T. urticae*. For chemicals used to control this mite see page

The Linnean name *T. telarius* has now been sunk taxonomically and replaced by two species, *T. cinnabarinus* the pantropical species which has a red-coloured summer female, and *T. urticae* the temperate species with a green-coloured summer female. The winter females (green) of both species are indistinguishable, even by the taxonomic experts, and the precise status of these two 'species' is not yet really clear, but both names are accepted for use. Most distribution records are not clearly attributable to either species.

Control. A predaceous mite *Phytoseilus riegeli* (Phytoseidae) has been used in glasshouses in Europe for the control of *T. urticae* with considerable success This predator has been used in field control of *T. cinnabarinus* in areas of both Kenya and Uganda.

Chemical control measures are not usually required; but, if very heavy infestations are found early in the season, foliar sprays of dimethoate are recommended. Other pesticides generally effective against this pest are demeton-*S*-methyl, derris, dichlorvos, dicofol, formothion, malathion, oxydemeton-methyl, petroleum oil, phosphamidon, quinomethionate, tetradifon and vamidothion, according to the crop concerned and the conditions at the time of spraying.

Fig. 9.340. Tetranychus cinnabarinus (Carmine Spider Mite); Kenya.



Brevipalpus phoenicis (Geijskes)

Common name. Red Crevice Tea Mite/Scarlet Mite
Family. Tenuipalpidae (= Phytoptipalpidae)
Hosts (main). Tea, and *Citrus*, Passion Fruits.

(alternative). Coffee, rubber, *Phoenix* spp., *Grevillea* shade trees, and many other trees.

Damage. Corky areas are to be found on the undersides of leaves, especially between the main veins at the petiole end of the leaves; the leaves may then dry up and will be prematurely shed. Numerous tiny red mites can be seen in the bark crevices of the new wood.

Pest status. A sporadic pest of tea in many parts of the world; a few bushes may be very heavily attacked, leaving the majority almost free from attack. There are a number of records from glasshouses in Europe.

Life history. The eggs are oval, about 0.1 mm long and bright red. They are stuck firmly to the undersides of leaves or in crevices in young bark. They hatch after about ten days.

The larva is a six-legged, scarlet creature which grows to a length of 0.15 mm.

After a resting stage of a few days a protonymph emerges from the larval skin. After feeding for about a week there is a second resting stage, from which emerges the deutonymph. Both nymphal stages are flat-bodied, oval in outline and scarlet. They both have four pairs of legs.

After a further resting period the adult mite emerges from the skin of the deutonymph. Adults resemble the nymphs but are somewhat larger, reaching a length of 0.3 mm. Each female mite may lay an average of one egg per day for a period of 7–8 weeks.

All active stages feed on the undersides of leaves, especially between the main veins at the petiole end. Leaves of all ages are attacked.

The total life-cycle takes about six weeks.

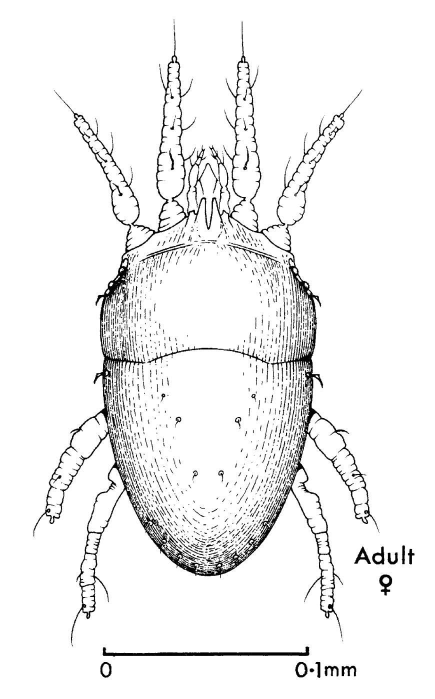
Distribution. Possibly a cosmopolitan species throughout the warmer parts of the world, but the records to date are very scattered. (CIE map no. A106).

Three other important polyphagous pest species include:-
B. californicus (Banks)
B. lewisi McG. (Citrus Flat Mite)
B. obovatus Donn. (Privet Mite) (CIE map no. A. 128)

Control. Recommended control practice is to spot-spray the affected bushes with either dicofol or chlorobenzilate.

In severe infestations the spray should be repeated 2–3 weeks later.

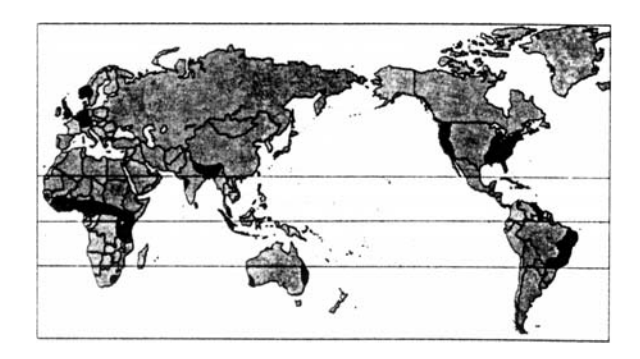
Fig. 9. 341. Brevipalpus phoenicis, adult ♀ Kenya.



Polyphagotarsonemus latus (Banks)
(= *Tarsonemus latus* Banks)

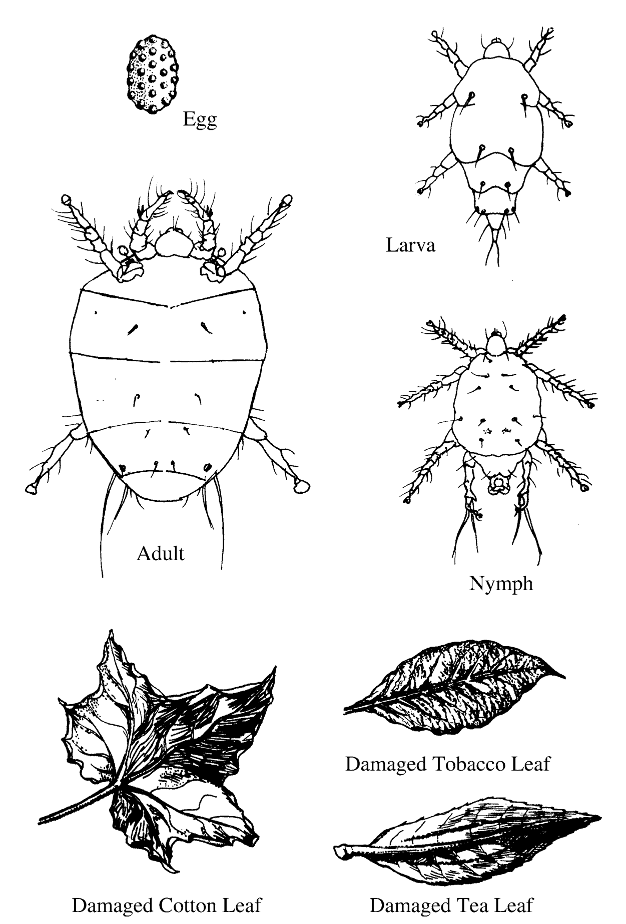
Common name. Broad Mite (Yellow Tea Mite)
Family. Tarsonemidae
Hosts. Totally polyphagous on a wide range of agricultural crops, ornamentals and wild plants (more than 50 recorded), including trees, shrubs and herbaceous plants.
Damage. Young leaves are cupped or distorted; with browned areas between the main veins, often bounded laterally by two distinct brown lines parallel to the main vein. With heavy infestations the flush growth is killed and herbaceous plants may die.
Pest status. A widespread pest of regular occurrence on many crops; usually a minor pest but occasionally serious.
Life history. Eggs are laid singly, stuck to the underside of flush leaves; they are oval in shape, flattened ventrally, and dorsally with rows of white tubercles; each egg is about 0.7 mm long. Hatching requires 2–3 days.

The larva is the only active immature stage; it is white and feeds near the old egg-shell; its development takes only 2–3 days. Nymphal development takes place within the larval skin, until the adult is formed, within 2–3 days. Female pupae are usually picked up by adult males and are carried on to newly opened young leaves attached to the abdomen tip. Adults are yellow and about 1.5 mm long. The female lives for about ten days and lays 2–4 eggs per day. All stages are found on the underside of flush leaves, usually in the grooves between the two halves of the leaf lamina before it has unfurled (causing the two parallel brown lines when the leaf is expanded).



Development can be completed in as short a time as 4–5 days in the summer, and 7–10 days in the winter.
Distribution. Distribution is very widespread, but records are sparse in some regions; more abundant in the tropics and subtropics, and in the colder temperate regions confined to greenhouses (CIE map no. A.191).
Control. This species is susceptible to sulphur, and dusting with sulphur is still recommended, as also is the use of dicofol, chlorobenzilate and carbophenothion in successive sprays.

Fig. 9.342. Polyphagotarsonemus latus (Broad Mite); Kenya.



Eriophyes sheldoni (Ewing)
(= *Aceria sheldoni* (Ewing))

Common name. Citrus Bud Mite
Family. Eriophyidae
Hosts (main). *Citrus* spp., especially lemon.
(alternative). None recorded – it appears to be confined to *Citrus*.
Damage. Twigs are bunched and twisted, blossoms misshapen, and fruits often assume grotesque shapes.
Pest status. A sporadically serious pest of all *Citrus* spp. in various parts of the world. Especially serious on grapefruit and lemon trees.
Life history. The eggs are extremely small, whitish, spherical objects (about 0.04 mm).

The larva is a minute triangular shape, about 0.1 mm long.

After a quiescent period the nymph emerges from the larval skin. It is about 0.13 mm long, cylindrical, but tapering at the posterior end. Only two pairs of legs are present, and these at the anterior end.

After a second quiescent period the adult emerges. It generally resembles the nymph but is yellowish or pinkish and about 0.18 mm long.

All stages of mite are found in protected places between the leaves or scales or developing buds. The total life-cycle takes 1–3 weeks, according to temperature.
Distribution. Recorded from the Mediterranean (Spain, Cyprus, Israel, Turkey, Italy, Sicily, Greece), Africa (Algeria, Zaïre, Kenya, Libya, S. Africa, Zimbabwe, Tunisia, Uganda), Java, Australia (Queensland, New South Wales), Hawaii, USA (Florida, California), S. America (Brazil and Argentina) (CIE map no. A127). (revised)
Control. The usual control recommendation is to spray infested trees at periods of blossom or flush growth with either lime-sulphur or chlorobenzilate, as a full-cover spray using as high a nozzle pressure as possible.

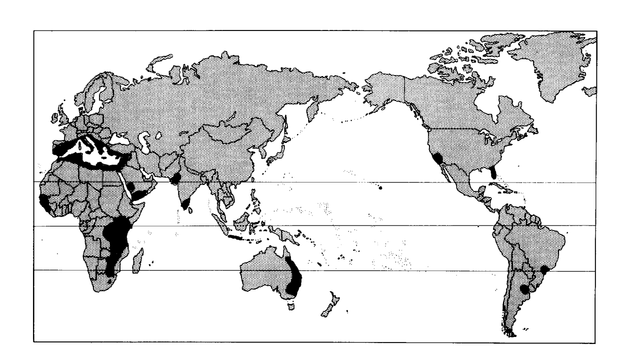
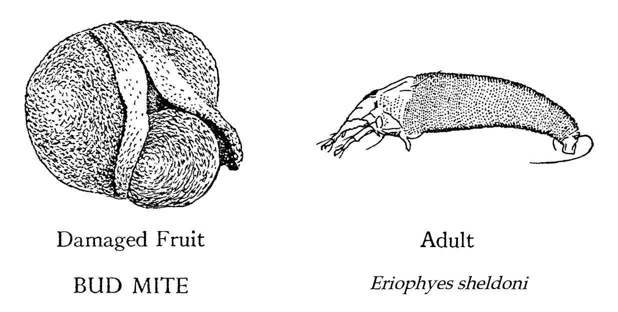


Fig. 9.343. Eriophyes sheldoni (Citrus Bud Mite); Kenya.



Phyllocoptruta oleivora (Ashmead)

Common name. Citrus Rust Mite
Family. Eriophyidae
Hosts (main). *Citrus* spp.

(alternative). Apparently confined to *Citrus* as a host, but *Fortunella* is recently recorded.

Damage. Lemon fruits become a silver colour; oranges and grapefruits russet-coloured. The skins of injured fruit are thicker than usual and the fruits are smaller. Leaves and young shoots may also be damaged.

Pest status. A common and locally serious *Citrus* pest in many countries.

Life history. Eggs are minute, spherical, whitish, and laid in depressions on the fruit or leaves. They hatch after 3–7 days.

The larva is very small, yellowish, and has a worm-like tapering cylindrical shape with two pairs of short legs at the anterior end. Larval stage lasts 2–4 days.

After a quiescent period the nymph emerges from the larval skin. The nymph is similar to the larva but more yellow and slightly larger. The nymphal stage also lasts 2–4 days.

After a second quiescent period the adult emerges from the nymphal skin. It generally resembles the nymph but is somewhat darker. Adults are about 0.1 mm long. Males have not been recorded. The female lives for about two weeks, during which time she lays 20–30 eggs.

Distribution. Almost cosmopolitan throughout the warmer parts of the world; recorded from Europe (Italy, Malta, Yugoslavia), Near East (Cyprus, Iran, Israel, Gaza Strip, Jordan, Lebanon, Turkey, Syria), USSR (Georgia, Krasnodar Krai), Africa (Angola, Zaïre, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Nigeria, Senegal, S. Africa, Tanzania, Uganda, Zambia), Bangladesh, India, China, Japan, Philippines, Taiwan, S. Vietnam, Australia (Queensland, New South Wales, Western Australia), Fiji, Hawaii, Cook Isles, USA (Florida, California, Alabama, Louisiana, Mississippi, Texas), C. America (Mexico, Guatemala), W. Indies, and S. America (Argentina, Brazil, Colombia, Ecuador, Peru, Uruguay, Venezuela).

Control. Fruits should be examined regularly with a good hand lens from blossom shed onwards. They are usually damaged when about 20–30 mm in diameter. The recommended sprays are either lime-sulphur or chlorobenzilate, as sprays to run-off taking particular care to wet the fruits. The fruits should be examined after 4–5 days with a hand lens and if living mites are present the spray should be repeated

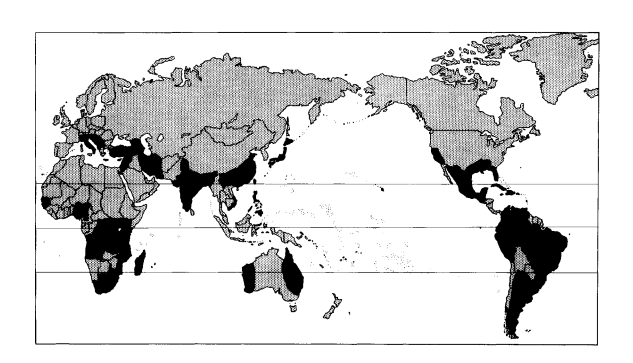
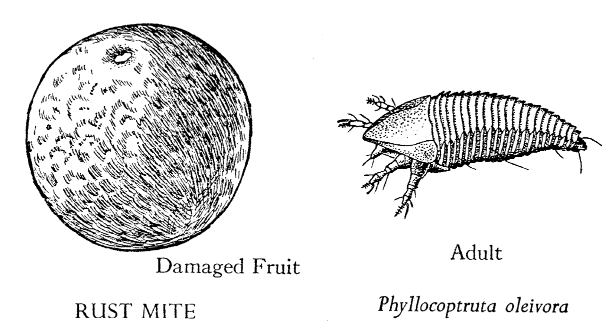


Fig. 9.344. Phyllocoptruta oleivora (Citrus Rust Mite); Kenya.



10 *Major tropical crops and their pest spectra*

Crops included

Almond
Apple
Apricot
Avocado
Bamboo
Bananas
Beans and grams
Betel palm
Betel-pepper
Brassicas
Breadfruit
Capsicums
Cardamom
Cashew
Cassava
Castor
Chickpea
Cinchona
Cinnamon
Citrus
Clove
Cocoa
Coconut
Cocoyam
Coffee
Cotton
Cowpea
Cucurbits
Custard apple
Date palm
Deccan hemp
Eggplant
Fig
Ginger
Grapevine
Grass
Groundnut
Guava
Hemp
Hyacinth bean
Jackfruit
Jujube
Jute
Kapok
Kola
Lentil
Lettuce
Litchi
Longan
Loquat
Macadamia
Maize
Mango
Manila hemp
Millets
Mulberry
Nutmeg
Oil palm
Okra
Olive
Onions
Opium poppy
Papaya
Passion fruit
Pea
Peach
Pecan
Pepper
Pigeon pea
Pineapple
Pistachio
Plum
Pomegranate
Potato
Pyrethrum
Quince
Rambutan
Rice
Rose apple
Roselle
Rubber
Safflower
Sann hemp
Sapodilla
Sesame
Sisal
Sorghum
Soybean
Sugarcane
Sunflower
Sweet potato
Tamarind
Taro
Tea
Tobacco
Tomato
Turmeric
Vanilla
Walnut
Watercress
Wheat (incl. barley and oats)
Yam
Pests of seedlings and general pests
Pests of stored products

ALMOND (*Prunus amygdalus* – Rosacea)

A native of eastern Mediterranean region; occurs as two distinct varieties, var. *dulcis* is the Sweet Almond, and var. *amara* is the Bitter Almond. The tree is small and closely resembles the near-relative peach. The trees are often cultivated as ornamentals for their convenient size and delicate blossoms. The nuts are very popular, and this is probably the nut sold in largest quantities in the world. The seed is eaten green, though most frequently roasted or salted, and also made into paste for cake making. There are many cultivars with quite different shell thicknesses and seed flavour. The bitter almond contains a bitter glucoside (amygdalin) which readily breaks down into cyanic acid and so prevents its use as food. However, it is grown in southern Europe as a source of the oil of bitter almond, which is used after the cyanic acid is extracted, for flavouring. The bitter almond trees are also used as stock for grafting sweet almonds on to. Sweet almonds are grown throughout southern Europe, S. Africa, Australia and California.

MAJOR PESTS				
Pterochloroides persicae Chol.	Peach Aphid	Aphididae	Mediterranean, C. Asia	Infest foliage
Cimbex quadrimaculatus Mull.	Sawfly	Cimbicidae	Italy, E. Med.	Larvae defoliate
Eurytoma amygdali End.	Almond Stone Wasp	Eurytomidae	Bulgaria, Greece, Iran, Turkey, Afghanistan, S. Russia	Larvae bore in kernel of fruit
Cossus cossus L.	Goat Moth	Cossidae	Europe, E. Med., C. Asia	Larvae bore branches
Ephestia cautella (Hb.)	Almond Moth	Pyralidae	Cosmopolitan in warmer countries	Larvae feed on kernel
Paramyelois transitella (Wlk.)	Navel Orangeworm	Pyralidae	USA (California)	Larvae bore fruits
Odinodiplosis amygdali (Anag.)	Almond Gall Midge	Cecidomyiidae	Greece, Lebanon	Larvae destroy flowers & fruits
Capnodis spp.	Flat-headed Borers	Buprestidae	W. Palaearctic	Larvae bore branches
Aceria phloeocoptes (Nal.)	Almond Bud Mite	Eriophyidae	Europe, C. Asia	Gall buds
MINOR PESTS				
Myzus persicae (Sulz.)	Green Peach Aphid	Aphididae	India	Infest foliage
Hyalopterus pruni Koch.	Mealy Plum Aphid	Aphididae	Palaearctic	Infest foliage
Brachycaudus helichrysi Kalt.	Peach Leaf-curl Aphid	Aphididae	India	Cause leaf-curl
Didesmococcus onifasciatus	Soft Scale	Coccidae	Lebanon, S. Russia, Afghanistan	Infest foliage
Pseudaulacaspis pentagona (Targ.)	White Scale	Diaspididae	India	Infest foliage
Monosteira lobuliferia Reut.	Lace Bug	Tingidae	Lebanon, Libya, Syria	Sap-sucker; toxic saliva
Anarsia lineatella Zell.	Peach Twig Borer	Gelechiidae	USA (California)	Larvae bore shoots
Cydia funebrana (Treit.)	Red Plum Maggot	Tortricidae	Europe, Asia	Larvae bore fruits
Cydia molesta (Busck)	Oriental Fruit Moth	Tortricidae	USA (California)	Larvae bore fruits
Malacosoma indica Wlk.	Tent Caterpillar	Lasiocampidae	India	Larvae defoliate
Polyphylla fullo L.	Chafer Beetle	Scarabaeidae	E. Med., Greece, S. Russia	Adults defoliate
Mimastra cyanura Hope	Leaf Beetle	Chrysomelidae	India	Adults eat leaves
Cerambyx clux Fald.	Longhorn Beetle	Cerambycidae	E. Med., Greece	Larvae bore trunk
Sphenoptera lafertei Thom.	Stem Borer	Buprestidae	India	Larvae bore trunk
Ruguloscolytus amygdali Guen.	Almond Bark Beetle	Scolytidae	Med.	Adults bore trunk
Ruguloscolytus spp.	Bark Beetles	Scolytidae	Med.	Adults bore bark
Myllocerus spp.	Grey Weevils	Curculionidae	India, E. Africa	Adults eat leaves
Otiorhynchus cribricollis Gylh.	Apple Weevil	Curculionidae	Med., Australia, W. USA	Adults eat leaves; larvae eat roots
Tanymecus cribricollis Gylh.	Southern Grey Weevil	Curculionidae	E. Europe	Adults eat leaves
Bryobia rubrioculus Schent.	Brown Mite	Tetranychidae	E. Med., Iran, Afghanistan	Scarify leaves

APPLE (*Pyrus malus* – Rosaceae)

Apple is essentially a temperate fruit, native to E. Europe and W. Asia, and has been cultivated for more than 3000 years. Some 6500 horticultural forms are known. The crop is grown commercially in Britain, Europe, Canada, N. USA, Australia, New Zealand and in some sub-tropical areas such as S. Africa, the Mediterranean region and in the cooler parts of India. There is a recent trend generally for crop diversification in most countries, and this has led to the introduction of apples as a crop to parts of Indonesia, Philippines and Kenya, in areas of high altitude where the climate is more sub-tropical.

MAJOR PESTS				
Psylla mali Sch.	Apple Sucker	Psyllidae	Europe, India	Nymphs destroy flower trusses
Rhopalosiphum insertum (Wlk.)	Apple-grass Aphid	Aphididae	Europe	Infest leaves
Dysaphis mali (Ferr.)	Rosy Apple Aphid	Aphididae	Europe	Infest foliage
Aphis pomi (Deg.)	Green Apple Aphid	Aphididae	Europe, W. Asia, N. America	Infest leaves
Dysaphis devecta (Wlk.)	Rosy Leaf-curling Aphid	Aphididae	Europe	Infest leaves
Eriosoma lanigerum (Ham.)	Woolly Apple Aphid	Pemphigidae	Cosmopolitan (esp. Iran)	Infest foliage
Quadraspidiotus perniciosus (Comst.)	San José Scale	Diaspididae	Cosmopolitan	Infest foliage & fruit; very damaging
Lygocoris pabulinus (L.)	Common Green Capsid	Miridae	Europe	Sap-sucker; toxic saliva
Cydia pomonella (L.)	Codling Moth	Tortricidae	Cosmopolitan	Larvae bore fruits
Archips podana (Scop.)	Fruit Tree Tortrix	Tortricidae	Europe	Larvae feed on flowers & buds
Operophtera brumata (L.)	Winter Moth	Geometridae	Europe	Larvae defoliate
Hoplocampa testudinea (Klug.)	Apple Sawfly	Tenthredinidae	Europe, N. America	Larvae damage fruitlets
Panonychus ulmi (Koch)	Fruit Tree Red Spider Mite	Tetranychidae	Europe	Scarify leaves
MINOR PESTS				
Empoasca spp.	Green Leafhoppers	Cicadellidae	Europe, N., C. & S. America	Infest foliage
Typhlocyba spp.	Fruit Tree Leafhoppers	Cicadellidae	Europe, Australia, NZ	Infest foliage
Aphis gossypii Glov.	Cotton Aphid	Aphididae	India	Infest foliage
Lachnus krishnii Glov.	Pear Aphid	Aphididae	India	Infest foliage
Hemiberlesia spp.	'Mealybugs'	Margarodidae	India	Infest foliage
Icerya purchasi Mask.	Cottony Cushion Scale	Margarodidae	India	Infest foliage
Parthenolecanium persicae (F.)	Peach Scale	Coccidae	Cosmopolitan	Infest foliage
Lepidosaphes ulmi (L.)	Oystershell Scale	Diaspididae	Cosmopolitan	Infest twigs
Aspidiotus nerii Bche.	Oleander Scale	Diaspididae	Europe, Africa, Australasia, N., C. & S. America	Infest foliage
Parlatoria oleae (Colv.)	Olive Scale	Diaspididae	Europe, India, N. & S. America	Infest foliage
Pseudaulacaspis pentagona T.	White Scale	Diaspididae	India	Infest foliage
Quadraspidiotus ostraeformis (Curt.)	Oystershell Scale	Diaspididae	Europe	Infest foliage
Helopeltis antonii S.	Capsid Bug	Miridae	India	Sap-sucker; toxic saliva; scar fruitlets, may kill shoots
Lygus viridanus M.	Capsid Bug	Miridae	India	
Plesiocoris rugicollis Fall.	Apple Capsid	Miridae	Europe	
Thrips flavus Schm.	Flower Thrips	Thripidae	India	Infest flowers
Thrips hawaiiensis (Morg.)	Thrips	Thripidae	India	Infest foliage
Ametastegia glabrata (Fall.)	Dock Sawfly	Tenthredinidae	Europe	Larvae defoliate
Vespula/Vespa spp.	Common Wasps	Vespidae	Cosmopolitan	Adults puncture ripe fruits
Dasyneura mali (Kieff.)	Apple Leaf Midge	Cecidomyiidae	Europe	Larvae roll leaves
Thomasiniana oculiperda (Rubs.)	Red Bud Borer	Cecidomyiidae	Europe	Larvae bore buds of young stock
Dacus spp.	Fruit Flies	Tephritidae	India	Larvae bore fruits
Rhagoletis pomonella (Walsh)	Apple Fruit Fly	Tephritidae	USA	Larvae bore fruits

(continued)

Synanthedon myopiformis (Bork.)	Apple Clearwing Moth	Sesiidae	Europe	Larvae bore under bark
Alsophila aescularia (Schiff.)	March Moth	Geometridae	Europe	Larvae defoliate
Erannis defoliaria (Clerck)	Mottled Umber Moth	Geometridae	Europe	Larvae defoliate
Zeuzera spp.	Leopard Moths	Cossidae	Europe, Med., India, Japan, USA	Larvae bore branches
Yponomeuta spp.	Small Ermine Moths	Yponomeutidae	Europe	Larvae defoliate
Adoxophyes orana (F.v.R.)	Summer Fruit Tortrix	Tortricidae	Europe, China	Larvae eat fruit surface
Acroclita naevana Hbn.	Tortrix Moth	Tortricidae	Europe, India	Larvae eat leaves
Cacaecia oporana L.	Fruit Tree Tortrix	Tortricidae	Europe	Larvae damage fruits
Cydia funebrana (Treit.)	Red Plum Maggot	Tortricidae	Europe, Asia	Larvae bore fruits
Epiphyas postvittana (Wlk.)	Light Brown Apple Moth	Tortricidae	Australia, Hawaii, NZ	Larvae damage fruits
Pammene rhediella (Clerck)	Fruitlet Mining Tortrix	Tortricidae	Europe	Larvae eat leaves
Spilonota ocellana Schiff.	Bud Moth	Tortricidae	Europe, India	Larvae bore buds
Orthosia spp.	Leaf-eating Caterpillars	Noctuidae	Europe	Larvae eat leaves
Malacosoma indica Wlk.	Tent Caterpillar	Lasiocampidae	India	Larvae defoliate
Arctias selene Hbn.	Moon Moth	Saturniidae	India	Larvae defoliate
Smerinthus ocellata (L.)	Eyed Hawk Moth	Sphingidae	Europe, USA	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantriidae	Europe, India	Larvae defoliate
Orygia spp.	Tussock Moths	Lymantriidae	Europe, Australia	Larvae defoliate
Merista spp.	Leaf Beetles	Chrysomelidae	India	Adults eat leaves
Eubrachis indica Baly	Apple Shoot Beetle	Chrysomelidae	India	Shoot bored
Brahmina spp.	Cockchafers	Scarabaeidae	India	Adults damage young fruits & flowers, and eat pieces of leaves; larvae in soil
Melolontha spp.	Cockchafers	Scarabaeidae	Europe, India	
Serica spp.	Cockchafers	Scarabaeidae	Europe, India	
Xylotrupes gideon L.	Unicorn Beetle	Scarabaeidae	India	
Adoretus spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves & flowers
Anomala spp.	Flower Beetles	Scarabaeidae	India	
Popillia spp.	Flower Beetles	Scarabaeidae	India	
Sphenoptera lafertei Thom.	Jewel Beetle	Buprestidae	India	Larvae bore trunk
Apriona cinerea Chev.	Longhorn Beetle	Cerambycidae	India	Larvae bore trunk
Betula spp.	Longhorn Beetles	Cerambycidae	India	Larvae bore trunk
Dorysthenus hugelii Redt.	Apple Root Borer	Cerambycidae	India	Larvae bore trunk & roots
Lophosternus hugelii Redt.	Longhorn Beetle	Cerambycidae	India	Larvae bore trunk
Anthonomus pomorum (L.)	Apple Blossom Weevil	Curculionidae	Europe	Larvae eat flowers
Caenorhinus aequatus (L.)	Apple Fruit Rhynchites	Curculionidae	Europe	Adults hole fruitlets
Rhynchites coeruleus (Deg.)	Apple Twig Cutter	Curculionidae	Europe	Adults cut off shoots
Phyllobius spp.	Leaf Weevils	Curculionidae	Europe	Adults eat leaves
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Scolytus rugulosus (Muller)	Fruit Bark Borer	Scolytidae	Eurasia, N. & S. America	Adults bore bark
Aculus schlechtendali (Nal.)	Leaf & Bud Mite	Eriophyidae	Europe, Canada, USA	Blister leaves
Eriophyes pyri (Pgst.)	Pear Leaf Blister Mite	Eriophyidae	Europe, S. Africa, Australia, NZ, N. & S. America	Blister leaves
Bryobia spp.	Brown Mites	Tetranychidae	Europe	Scarify leaves
Tetranychus urticae (Koch)	Temperate Red Spider Mite	Tetranychidae	Europe, Australia	Scarify leaves

APRICOT (*Prunus armeniaca* – Rosaceae)

A native of Asia, this small tree (6–10 m tall) has long been cultivated in China, India, Egypt, and Iran, and is now grown in Europe, parts of Africa, and the warmer parts of the New World. This plant is susceptible to frost, so is grown in warm temperate regions and the sub-tropics. The fruit is like a peach but the stone is smooth. Apricots are used as table fruits in the areas where they are grown, and are also dried, frozen, canned, candied, and made into a paste; an oil is extracted from the seeds.

MAJOR PESTS				
Quadraspidiotus perniciosus (Comst.)	San José Scale	Diaspididae	India	Infest foliage
Anarsia lineatella Zell.	Peach Twig Borer	Gelechiidae	India	Larvae bore buds
MINOR PESTS				
Hyalopterus pruni (Geoff.)	Mealy Plum Aphid	Aphididae	India	Infest foliage
Brachycaudus helichrysi Kalt.	Peach Leaf-curl Aphid	Aphididae	India	Infest foliage
Myzus persicae (Sulz.)	Green Peach Aphid	Aphididae	India	Infest foliage
Eulecanium corylil L.	Soft Scale	Coccidae	India	Infest foliage
Parthenolecanium corni (Bch.)	Plum Scale	Coccidae	Europe, W. Asia	Infest foliage
Drosicha mangiferae (Green)	Mango Giant Mealybug	Margarodidae	India	Infest foliage
Eucosma ocellana Schiff.	Bud Caterpillar	Tortricidae	India	Larvae bore buds
Cacoecia sarcostega Meyr.	–	Tortricidae	India	Larvae feed on buds
Cydia funebrana (Treit.)	Red Plum Maggot	Tortricidae	Europe, Asia	Larvae bore fruits
Archips spp.	Fruit Tree Tortrixes	Tortricidae	India	Larvae feed on buds
Malacosoma indica Wlk.	Tent Caterpillar	Lasiocampidae	India	Larvae defoliate
Lymantria obfuscata Wlk.	Tussock Moth	Lymantriidae	India	Larvae defoliate
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	India	Larvae inside fruits
Brahmina spp.	Cockchafers	Scarabaeidae	India	Adults eat leaves
Melolontha spp.	Cockchafers	Scarabaeidae	India	Adults eat leaves
Serica spp.	Cockchafers	Scarabaeidae	India	Adults eat leaves
Anomala spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves
Adoretus spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves
Sphenoptera lafertei Thom.	Stem Borer	Buprestidae	India	Larvae bore trunk
Aeolesthes holosericea F.	Apple Stem Borer	Cerambycidae	India	Larvae bore trunk
Dorysthenes hugeli Redt.	–	Cerambycidae	India	Larvae bore trunk
Lophosternus hugelii Redt.	Stem Borer	Cerambycidae	India	Larvae bore trunk
Mimastra cyanura Hope	Almond Beetle	Chrysomelidae	India	Adults defoliate
Amblyrrhinus poricollis Boh.	Plum Weevil	Curculionidae	India	Adults eat leaves
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves

AVOCADO (*Persea americana* – Lauraceae)

Avocado originated from C. America, was introduced into the W. Indies in the mid-17th century, and spread into Asia by the mid-19th century. Now it is grown in most tropical and sub-tropical countries. The main commercial crop-producing countries are S. Africa, Hawaii, Australia, USA. C. and S. America. It occurs as three ecological races of a single species; the West Indian race produces the best fruit, but hybrids are now cultivated. It will grow in a variety of soils but cannot stand waterlogging, and is liable to wind damage. The best fruit are grown in the lowland hot tropics. The fruit is a large fleshy single-seeded berry, pyriform in shape, green in colour, with a high oil content rich in vitamins A, B and E. The tree is evergreen and grows to a height of about 20 m at the most. (See also D. Smith, 1973).

MAJOR PESTS

Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	Pantropical	Infest leaves
Amblypelta spp.	Fruit-spotting Bugs	Coreidae	E. Australia	Necrotic spots on fruit
Dacus ferrugineus (F.)	Fruit Fly	Tephritidae	Malaysia	Larvae in fruits
Dacus spp.	Fruit Flies	Tephritidae	S.E. Asia, Australia	Larvae in fruits
Solenopsis geminata (F.)	Fire Ant	Formicidae	India, S.E. Asia	Sting workers
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	W. Africa	Larvae bore fruits

MINOR PESTS

Aleurodicus dispersus Russell	Whitefly	Aleyrodidae	C&S America, Pacific	Infest leaves
Aleurotuberculatus psidii (Singh)	Guava Whitefly	Aleyrodidae	Malaysia	Infest leaves
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Cosmopolitan (Philippines)	Infest foliage
Ceroplastes spp.	Waxy Scales	Coccidae	E. Australia	Encrust foliage
Nipaecoccus nipae (Mask.)	Nipa Mealybug	Pseudococcidae	Africa, India, C. America	Encrust foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	S.E. Asia	Infest stems
Pseudococcus spp.	Mealybugs	Pseudococcidae	S.E. Asia	Encrust stems
Gascardia destructor (Newst.)	White Waxy Scale	Margarodidae	E. Australia	Encrust twigs
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	On fruits & twigs
Pseudaonidia trilobitiformis (Green)	Trilobite Scale	Diaspididae	Pantropical	On fruits & twigs
Hemiberlesia lataniae (Sign.)	Latania Scale	Diaspididae	E. Australia	On fruits & twigs
Colgar sp.	Moth Bug	Flattidae	Papua NG	Sapsucker
Terentius nubifasciatus	Treehopper	Membracidae	Papua NG	Sapsucker
Euricania villica	Ricanid Planthopper	Ricaniidae	Papua NG	Sapsucker
Tarundia glaucesenus	Ricanid Planthopper	Ricaniidae	Papua NG	Sapsucker
Helopeltis spp.	Capsid Bugs	Miridae	Africa, S.E. Asia, India	Attack shoots; toxic saliva
Selenothrips rubrocinctus (Giard)	Red-banded Thrips	Thripidae	S.E. Asia, India	Infest leaves
Dacus dorsalis (Hend.)	Oriental Fruit Fly	Tephritidae	Philippines	Larvae in fruits
Clania gigantea (Dndg.)	Giant Bagworm	Psychidae	S.E. Asia	Larvae defoliate
Oiketicus elongatus Saund.	Large Bagworm	Psychidae	E. Australia	Larvae defoliate
Paramyelois transitella (Wlk.)	Navel Orangeworm	Pyralidae	USA (California)	Larvae bore fruits
Attacus atlas (L.)	Atlas Moth	Saturniidae	Malaysia, Philippines	Larvae defoliate
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	Philippines	Larvae bore branches
Papilio spp.	Swallowtails	Papilionidae	Philippines	Larvae defoliate
Lophodes miserana (Wlk.)	Brown Looper	Geometridae	E. Australia	Larvae defoliate
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae eat roots
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Niphonoclea spp. twigs	Twig Borers	Cerambycidae	Philippines	Larvae bore twigs
Monolepta australis (Jac.)	Red-shouldered Leaf Beetle	Chrysomelidae	E. Australia	Destroy foliage
Platypus bicornis (Schedl.)	Pin-hole Borer	Platypodidae	Malaysia	Adults bore bark
Carpophilus marginellus (Mots.)	Sap Beetle	Nitidulidae	Malaysia	Larvae bore fruit
Xylosandrus compactus (Eichh.)	Black Twig Borer	Scolytidae	India, S.E. Asia	Adults bore twigs
Xyleborus morstatti Hagdn.	Shot-hole Borer	Scolytidae	India	Adults bore twigs
Xyleborus fornicatus Eichh.	Tea Shot-hole Borer	Scolytidae	India, S.E. Asia	Adults bore twigs
Diaprepes abbreviatus (L.) roots	Sugarcane Root Weevil	Curculioniolae	C. America	Larvae damage roots
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Pantropical	Damage leaves

BAMBOO (*Bambusa vulgaris*, etc. – Gramineae)

About 45 genera, and more than 200 species, of woody perennials belong to the Bambuseae, generally regarded as the most primitive tribe within the Gramineae. They usually grow gregariously in clumps, the largest species being 20–30m in height. As a group they are found from sea-level to the snow line in the tropics, sub-tropics and warmer temperate regions of the world. The greatest number of species are found in the Indo-Malaysian region, extending through China to Korea and Japan. Africa only has a few species. The important species number less than ten, and most of the cultivated species are now unknown in the wild state. The uses of bamboo are many, for example in the building of houses, bridges, for scaffolding, making paper, furniture, weaving, the young shoot is eaten in China as a vegetable and the fruits provide an edible grain, although typically each bamboo clump only flowers once and then dies. Very important to rural communities in S&SE Asia.

MAJOR PESTS				
Dinoderus spp.	Small Bamboo Borers	Bostrychidae	India, China, Philippines Australia, Japan	Adults bore stems
Cyrtotrachelus longimanus	Bamboo Weevil	Curculionidae	S. China	Larva destroys shoot
MINOR PESTS				
Ceracris kiangsu Tsai	Bamboo Locust	Acrididae	S. China	Adults and nymphs defoliate
Locusta migratoria manilensis (Meyen)	Mig. Locust	Acrididae	Philippines	
Macrotermes spp.	Termites	Termitidae	Philippines	Workers eat roots
Pseudoregma bambusicola Tak.	Bamboo Woolly Aphid	Pemphigidae	S. China, Philippines	Encrust shoots
Purohita fuscovenosa Muir	Planthopper	Delphacidae	S. China	Feed on stems
Saccharicoccus sp.	Sugarcane Mealybug	Pseudococcidae	S. China, Philippines	Under leaf sheaths
Asterolecanium bambusae (Boisd.)	Bamboo Star Scale	Asterolecanidae	Philippines, USA	Encrust stem
Notobitus meleagris (F.)	Bamboo Bug	Coreidae	S. China	Toxic saliva scars stems
Xylocopa iridipennis Lep.	Bamboo Carpenter Bee	Xylocopidae	S. China	Nest in dead internodes
Tetramesa spp.	Bamboo Jointworms	Eurytomidae	Japan, USA	Larvae all shoots
Arge spp.	Sawflies	Argidae	S. China	Larvae defoliate
Atrachea vulagris	Shoot Borer	–	China	Larvae bore shoots
Agrotis segetum (Schiff.)	Common Cutworm	Noctuidae	China	Larvae are cutworms
Bambusiphila vulgaris Butler	Bamboo-shoot Cutworm		Japan	
Pyrausta coclesalis Wlk.	Bamboo Leafroller	Pyralidae	SE Asia, China, India	Larvae roll leaves
Erionota thrax L.	Banana Skipper	Hesperiidae	Philippines	Larvae roll leaves
Telicota augias (L.)	Rice Skipper	Hesperiidae	Philippines	Larvae roll leaves
Bostrychopsis parallela (Lesne)	Bamboo Borer	Bostrychidae	Philippines, China	Adult bores stems
Schizotetranychus celarius (Banks)	Bamboo Spider Mite	Tetranychidae	China, Japan, USA	Scarity foliage
Lethe spp.	Bamboo Broums	Nymphalidae	SE Asia	Larvae defoliate
Discophora sondaica	Bamboo Broums	Nymphalidae	SE Asia, China	
Dactylispa spp.	Bamboo Hispids	Chrysomelidae	Philippines	Larvae mine leaves
Chlorophorus annularis (F.)	Bamboo Longhorn	Cerambycidae	Philippines, S. China	Larvae bore stems
Xylotrechus nauticus	Longhorn Beetle	Cerambycidae	S. China	Larvae bore stems

BANANAS (*Musa sapientum* varieties – Musaceae)

Also known as plantain; there are many varieties, some with high sugar content eaten for dessert, some with high starch for cooking or beer-brewing. They occur wild in the area from India to New Guinea, but are now cultivated throughout the tropics. It is essentially a tropical crop, growing best on well-drained fertile soils; it cannot tolerate frost, and is very susceptible to wind damage. It is basically a giant herb with the pseudostem formed by the overlapping leaf bases. The fruit is formed as 'fingers' on a series of successional 'hands' along the flower stalk. The main production areas are Ecuador, C. America, W. Indies, W. Africa, Cameroons and the Pacific Islands.

MAJOR PESTS				
Pentalonia nigronervosa Coq.	Banana Aphid	Aphididae	Pantropical	Under leaf sheaths
Hercinothrips bicinctus Bagn.	Banana Thrips	Thripidae	E. Africa, Australia	Infest flowers
Nacoleia octasema (Meyr.)	Banana Scab Moth	Pyralidae	Indonesia	Larvae scab fruits
Erionota spp.	Banana Skippers	Hesperiidae	India, S.E. Asia, China	Larvae roll & eat leaves
Cosmopolites sordidus (Germ.)	Banana Weevil	Curculionidae	Pantropical	Larvae bore rhizome
Odoiporus longicollis (Oliv.)	Banana Stem Weevil	Curculionidae	S.E. Asia	Larvae bore stem
Colaspis hypochlora Lefevre	Banana Fruit-scarring Beetle	Chrysomelidae	C. & S. America	Larvae scar fruits
MINOR PESTS				
Hieroglyphus banian (F.)	Large Rice Grasshopper	Acrididae	Thailand, Laos	Adults & nymphs eat leaves
Sexava spp.	Longhorned Grasshoppers	Tettigoniidae	Papua NG	
Patanga succincta (L.)	Bombay Locust	Acrididae	Thailand, Laos	Adults & nymphs eat leaves
Aphisgossypii Glov.	Melon/Cotton Aphid	Aphididae	Pantropical	Sap suckers
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	Pantropical	Under leaves
Pseudococcus comstocki Kuw.	Banana Mealybug	Pseudococcidae	S.E. Asia	Encrust foliage
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	S.E. Asia, Africa	Encrust foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Encrust foliage
Ischnaspis longirostris (Sign.)	Black Line Scale	Diaspididae	Pantropical	Encrust foliage
Aonidiella aurantii (Mask.)	California Red Scale	Diaspididae	India	Encrust foliage
Aspidiotus spp.	Armoured Scales	Diaspididae	Old World tropics	Infest fruit & foliage
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	Africa, C. & S. America	
Pocillocarda mitrata Gerst.	Leafhopper	Cicadellidae	E. Africa	Infests leaves
Stephanitis typica (Dist.)	Banana Lace Bug	Tingidae	India, S.E. Asia, Korea, Japan	Sap-sucker; toxic saliva
Chaetanaphothrips signipennis (Bag.)	Banana Rust Thrips	Thripidae	India, Australia, C. America	Infest flowers & fruit
Hercinothrips femoralis (Reut.)	Banded Greenhouse Thrips	Thripidae	Cosmopolitan	Infest foliage
Heliothrips haemorrhoidalis (Bouché)	Black Tea Thrips	Thripidae	S.E. Asia	Leaves & fruit silvered
Thrips florum Schmutz	Banana Flower Thrips	Thripidae	Australia	Infest flowers
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	India, Australia, S.E. Asia	Larvae damage fruit
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India, S.E. Asia	Larvae eat leaves
Castniomera humbolti (Boisd.)	Banana Stem Borer	Castniidae	C. & S. America	Larvae bore pseudostem
Platynota rostrana (Wlk.)	–	Tortricidae	C. & S. America	Larvae damage fruit
Ceramidia viridis (Druce)	Leaf-cutting Caterpillar	Syntomidae	C. & S. America	Larvae defoliate
Ecpantheria icasia (Cramer)	Tiger Moth	Arctiidae	C. & S. America	Larvae eat fruit peel
Othreis fullonia (Cl.)	Fruit-piercing Moth	Noctuidae	Old World tropics	Adults pierce fruit
Latoia lepida (Cram.)	Blue-striped Nettlegrub	Limacodidae	India	Larvae defoliate
Dacus curvipennis Frogg.	Banana Fruit Fly	Tephritidae	Fiji	Larvae in fruits
Dacus spp.	Fruit Flies	Tephritidae	India, S.E. Asia, Australasia, Pacific	Larvae in fruits

(continued)

Trigona spp.	Fruit-scarring Bees	Apidae	C. & S. America	Adults scar fruits
Prionoryctes caniculus Arr.	Yam Beetle	Scarabaeidae	Africa	Larvae damage roots
Colaspis spp.	Banana Fruit-scarring Beetles	Chrysomelidae	India, C. & S. America	Adults scar fruits
Nodostoma spp.	Leaf Beetles	Chrysomelidae	India	Adults damage fruits
Sphaeroderma varipennis Jacoby	Leaf Beetle	Chrysomelidae	Thailand	Adults defoliate
Sphaeroderma spp.	Leaf Beetles	Chrysomelidae	Laos	Adults defoliate
Metamasius hemipterus L.	West Indian Cane Weevil	Curculionidae	W. Africa, W. Indies, S. America	Scarify flowers
Tomnoschoita nigroplagiata Qued.	–	Curculionidae	E. Africa, Zaire	Larvae bore stem
Philicoptus waltoni (Boh.)	–	Curculionidae	Philippines	Adults damage fruit
Araecerus fasciculatus (De. G.)	Coffee Bean Weevil	Anthribidae	Ghana, Thailand, Bermuda	Adults attack fruits
Doticus palmaris Pascoe	–	Anthribidae	Australia (Queensland)	Adults attack fruits
Tetranychus spp.	Red Spider Mites	Tetranychidae	Pantropical	Scarify foliage

More than 470 species of insects and mites recorded by Ostmark (1974) as major and minor pests of bananas.

BEANS AND GRAMS (*Phaseolus* spp. – Leguminosae)

(*P. vulgaris* – Common, Garden, French, Haricot, or Kidney Bean)
(*P. lunatus* – Lima Bean *P. coccineus* – Scarlet Runner Bean)
(*P. aureus* – Mung Bean, Green Gram *P. mungo* – Black Gram)
(*P. calcatus* – Rice Bean *P. angularis* – Adzuki Bean)
The species listed above are the usual ones referred to as beans and grams, but a few other obscure species are known. The plant is an annual climber, which can be made to assume a bushy habit in some species. The common bean is a native of S. America, as is also the lima bean (Peru and Brazil); scarlet runner is from C. America; mung bean, black gram and rice bean are ancient legumes from India; adzuki bean is of great importance in China and Japan. Growth requirements vary somewhat as some species are more temperate than others. The immature pods are cooked green as a vegetable, and the seeds may be dried and processed; the whole plant may be used as forage. As grain legumes these plants are an important source of plant protein in many parts of the world. Generally the different species of *Phaseolus* show a similar pest spectrum.

MAJOR PESTS				
Aphis fabae Scop.	Black Bean Aphid	Aphididae	Cosmopolitan (not Australia)	Infest foliage
Clavigralla spp.	Spiny Brown Bugs	Coreidae	Africa	Sap-suckers; toxic saliva
Lamprosema spp.	Bean Leaf Rollers	Pyralidae	India, S.E. Asia, S. America	Larvae roll leaves
Maruca testulalis (Geyer)	Mung Moth	Pyralidae	Pantropical	Larvae bore pods
Helicoverpa armigera (Hb.)	Bollworm	Noctuidae	Cosmopolitan in Old World	Larvae bore pods
Helicoverpa Zea	American Bollworm	Noctuidae	S. America	
Taeniothrips sjostedti (Tryb.)	Bean Flower Thrips	Thripidae	Africa	Infest flowers
Ophiomyia phaseolii (Tryon)	Bean Fly	Agromyzidae	Europe, Africa, India, S.E. Asia, Australasia	Larvae bore inside swollen stem
Delia platura (Meign.)	Bean Seed Fly	Anthomyiidae	Cosmopolitan	Larvae bore sown seed
Coryna spp.	Pollen Beetles	Meloidae	Africa	Adults eat pollen
Mylabris spp.	Banded Blister Beetles	Meloidae	Africa, India, S.E. Asia	Adults eat flowers
Epicauta spp.	Black Blister Beetles	Meloidae	Africa, Asia, S. America	Adults eat flowers
Epilachna varivestis Muls.	Mexican Bean Beetle	Coccinellidae	USA, Mexico	Adults & larvae defoliate
Diabrotica balteata	Corn Rootworm	Chrysomelidae	C. & S. America	Ads eat leaves, larval eat roots
Acanthoscelides obtectus (Say)	Bean Bruchid	Bruchidae	Cosmopolitan	Attack ripe seeds pods in stores
Callosobruchus spp.	Cowpea Bruchids	Bruchidae	Cosmopolitan in warmer regions	
Zabrotes subfasciatus	Mexican Bean Beetle	Bruchidae	C. & S. America & Africa	
Colaspis brunnea (F.)	Grape Colaspis	Chrysomelidae	Southern USA	Larvae feed on roots
Ootheca mutabilis (Sahlb.)	Brown Leaf Beetle	Chrysomelidae	E. Africa, Nigeria	Adults eat leaves
Apion spp.	Pod Weevils	Apionidae	Cosmopolitan	Infest flowers & pods
Tetranychus spp.	Red Spider Mites	Tetranychidae	Cosmopolitan	Scarify web foliage
MINOR PESTS				
Trialaurodes spp.	Whitefly	Aleyrodidae	Africa, S. American	Sap sucker, virus vector
Bemisia tabaci	Whitefly	Aleyrodidae	Cosmopolitan	Sap sucker, virus vectors
Empoasca spp.	Green Leafhoppers	Cicadellidae	Cosmopolitan	Infest foliage
Aphis craccivora Koch	Groundnut Aphid	Aphididae	Cosmopolitan	Infest foliage
Macrosiphum spp.	Aphids	Aphididae	Africa, S.E. Asia, S. America	Infest foliage
Coccus spp.	Soft Scales	Coccidae	Cosmopolitan	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Amblypelta spp.	Coreid Bugs	Coreidae	S.E. Asia	Sap-sucker; toxic saliva
Anaplocnemis horrida Germ.	Coreid Bug	Coreidae	Africa	Sap-sucker; toxic saliva
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	Africa, India, S.E. Asia, Australasia	Sap-sucker; toxic saliva

(continued)

Riptortus pedestris F.	Coreid Bug	Coreidae	India	Sap-sucker; toxic saliva
Lygus spp.	Capsid Bugs	Miridae	Europe, Africa	Sap-suckers; toxic saliva
Calocoris norvegicus (Gmel.)	Potato Capsid	Miridae	Europe	Sap-sucker; toxic saliva
Halticus tibialis	Capsid Bug	Miridae	S.E. Asia	Sap-sucker; toxic saliva
Lygocoris pabulinus (L.)	Common Green Capsid	Miridae	Europe	Sap-sucker; toxic saliva
Coptosoma cribraria F.	–	Pentatomidae	India	Sap-sucker; toxic saliva
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	Sap-sucker; toxic saliva
Taeniothrips cinctipennis (Bagn.)	Thrips	Thripidae	S.E. Asia	Infest flowers
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Infest foliage
Thrips palmi	Palm Thrips	Thripidae	S.E. Asia, China	Infest foliage
Kakothrips robustus (Uzel)	Pea Thrips	Thripidae	Europe	Infest flowers
Homona coffearia (Niet.)	Tea Tortrix	Tortricidae	S.E. Asia	Larvae roll leaves
Eucosma melanaula (Meyr.)	Leaf Roller	Tortricidae	India	Larvae roll leaves
Cnephasia spp.	Leaf Rollers	Tortricidae	Europe	Larvae roll leaves
Lampides boeticus L.	Pea Blue Butterfly	Lycaenidae	India	Larvae bore pods
Agrius convolvuli (L.)	Convolvulus Hawk Moth	Sphingidae	India	Larvae defoliate
Amsacta spp.	Red Hairy Caterpillar	Arctiidae	Africa, India	Larvae defoliate
Estigmene actea (Drury)	Saltmarsh Caterpillar	Arctiidae	C. & S. America	Larvae defoliate
Diacrisia obliqua Wlk.	Tiger Moth	Arctiidae	India	Larvae defoliate
Anticarsia gemmatalis (Hb.)	Velvetbean Caterpillar	Noctuidae	USA, S. America	Larvae bore pods
Anticarsia irrorata B.	Green Leaf Caterpillar	Noctuidae	India	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Asia, India, Australasia	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Achaea spp.	Semi-loopers	Noctuidae	Africa, S.E. Asia	Larvae defoliate
Plusia spp.	Semi-loopers	Noctuidae	S.E. Asia, India	Larvae defoliate
Ophiomyia spp.	Bean Flies	Agromyzidae	S.E. Asia	Larvae bore stem
Phytomyza horticola Gour.	Pea Leaf Miner	Agromyzidae	Cosmopolitan in Old World	Larvae mine leaves
Liriomza trifolü	Leaf Miner	Agromyzidae	USA, S. America	Larvae mine leaves
Delia trichodactyla Rond.	Bean Seed Fly	Anthomyiidae	Europe	Larvae bore sown seed
Tipula spp.	Leatherjackets	Tipulidae	Europe	Larvae damage seedlings
Epilachna spp.	Epilachna Beetles	Coccinellidae	S.E. Asia	Adults & larvae defoliate
Henosepilachna capensis (Thnb.)	Epilachna Beetle	Coccinellidae	S. Africa	Adults & larvae defoliate
Monolepta elegantula (Boh.)	Leaf Beetle	Chrysomelidae	Malaysia	Adults defoliate
Plagiodera inclusa Stål	Leaf Beetle	Chrysomelidae	India	Adults defoliate
Alcidodes spp.	Striped Weevils	Curculionidae	Africa, India	Adults girdle stems
Aperitmetus brunneus (Hust.)	Tea Root Weevil	Curculionidae	E. Africa	Larvae eat roots; adults eat leaves
Graphognathus spp	White-fringed Weevils	Curculionidae	Australia, USA, S. America	Larvae eat roots; adults eat leaves
Nematocerus spp.	Nematocerus Weevils	Curculionidae	E. Africa	Adults eat leaves
Oribius spp.	Leaf Weevils	Curculionidae	Papua NG	Adults eat leaves
Sitona spp.	Pea and Bean Weevils	Curculionidae	Europe	Adults eat leaves; larvae in root nodules
Aphis gossypü	Cotton Aphid	Aphididae	Cosmopolitan	Sack sap
Myzus persicae	Peach-Potato Aphid	Aphididae	Cosmopolitan	Virus vectors
Elasmopalpus lignosellus	Lesser Com stall Bores	Pyralidae	C. & S America	Larvae bore stem
Agrotis spp.	Cutworms	Noctuidae	Cosmopolitan	Larvae destroy seedlings.

(continued)

Urbanus proteus (L.)	Bean Leafroller	Hesperüdae	S. America	Larvae roll leaves.
Caliothrips braziliensis (Morgan)		Thripidae	S. America	Scarify folige
Epinota opposita, Hein.	Epinotia	Olethreutidae	S. America	Larvae bore buds pods
Laspeyresia leguminis Hein.		Tortricidae	S. America	Larvae bore pods
Several species	Whitegrubs	Scarabaeidae	S. America	Larvae eat roots
Polyphagotarsonemus latus		Tasonemidae	S. America	Leaves stunted

36 species of Chrysomelidae recorded in S. America

BETEL PALM (*Areca catechu* – Palmae)

Betel ‘nuts’ are the seeds of a palm native to Malaysia, but now widely grown throughout the tropics wherever the habit of betel chewing is practised, that is from Africa to India, S.E. Asia, and throughout the Pacific region. On a world basis it outrivals chewing gum as a masticatory. The hard dried endosperm of the seeds (both ripe and unripe), misnamed ‘nuts’, may be chewed alone, but the usual practice is to wrap pieces of nut in a leaf of betel-pepper on which a dab of slaked lime has been added. The quid is chewed slowly, causing continuous salivation, and the whole mouth becomes stained bright red. The practice of betel-chewing appears to be quite addictive, but is thought to be harmless. The plant is a tall slender monoecious palm, living for some 60–100 years. It flourishes in wet maritime climates in the tropics, and is grown at altitudes from sea-level up to 900 m.

MAJOR PESTS

MINOR PESTS

Cerataphis variabilis Hrl.	Coconut Aphid	Aphididae	India	Infest foliage
Icerya aegyptica (Dgl.)	Egyptian Fluted Scale	Margarodidae	India	Infest foliage
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	India	Encrust foliage
Pinnaspis spp.	Armoured Scales	Diaspididae	India	Encrust foliage
Coccus hesperidum L.	Soft Scale	Coccidae	India	Encrust foliage
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	India	Encrust foliage
Carvalhoia arecae Mill.	Areca Bug	Miridae	India	Sap-sucker; toxic saliva
Rhipiphorothrips cruentatus H.	Leaf Thrips	Thripidae	India	Infest foliage
Thrips hawaiiensis (Morg.)	Flower Thrips	Thripidae	India	Infest flowers
Contheyla rotunda	Slug Caterpillar	Limacodidae	India	Larvae defoliate
Amathusia spp.	Brown Butterflies	Amathasiinae (Nymphalidae)	SE Asia	Larvae defoliate
Leucopholis lepidophora Bl.	Cockchafer	Scarabaeidae	India	Adults eat leaves; larvae in soil eat roots
Promecotheca cummingii Baly	Coconut Hispid	Chrysomelidae	S.E. Asia	Larvae mine leaves
Araeocerus fasciculatus (De. G.)	Coffee Bean Weevil	Brenthidae	India	Larvae feed inside ‘nuts’
Coccotrypes carpophagus Horn.	Stored Arecanut Beetle	Scolytidae	India	Adults bore stored ‘nuts’

BETEL-PEPPER (*Piper betle* – Piperaceae)

This tall woody vine, native to Malaya, is cultivated for its leaves which are chewed together with betel nut as a masticatory. The habit is of great antiquity, and it is thought that more than 400 million people chew the betel pan, in an area from E. Africa, through India and S.E. Asia, to most of the Pacific region. A number of different cultivars are recognized in India. The pungency of the leaves is due to certain volatile oils (phenols), and the leaves are rich in vitamins B and C. In its wild state the plant grows in the tropical rain forests of Malaysia, but it may be grown under irrigation in drier areas providing the soil is fertile.

MAJOR PESTS

MINOR PESTS

Odontotermes obesus Ramb.	Scavenging Termite	Termitidae	India	Workers collect plant material
Aleurocanthus rugosa Singh	Whitefly	Aleyrodidae	India	Infest foliage
Aleyrodes spp.	Whiteflies	Aleyrodidae	India, S.E. Asia	Infest foliage
Dialurodes pallida Singh	Whitefly	Aleyrodidae	India	Infest foliage
Aphis gossypii Glov.	Cotton Aphid	Aphididae	India	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	Infest foliage
Planococcus citri (Risso)	Root Mealybug	Pseudococcidae	India	Infest roots
Lepidosaphes cornutus Ramk.	Betelvine Scale	Diaspididae	India	Infest foliage
Pachypeltis politus Dist.	Betelvine Bug	Miridae	India	Sap-sucker; toxic saliva
Cyclopelta siccifolia Westw.	Black Bug	Pentatomidae	India	Sap-sucker; toxic saliva

BRASSICAS (*Brassica* spp. – Cruciferae) (Cabbage, Kale, Cauliflower, Mustards, Broccoli, Turnip, Brussels Sprout, Rape)

An agriculturally diverse group of crops of European origin, and of great antiquity. They are cultivated from the Arctic to the sub-tropics, and at higher altitudes in the tropics. Certain species and varieties are more adapted to the tropics than others. As a group together with Radish (*Raphanus sativus*), they seem to have a similar spectrum of pests in most regions.

MAJOR PESTS				
Brevicoryne brassicae (L.)	Cabbage Aphid	Aphididae	Cosmopolitan in cooler regions	Infest foliage; virus vector
Lipaphis erysimi (Kalt.)	Turnip Aphid	Aphididae	Cosmopolitan in warmer regions	Infest foliage; virus vector
Aleyrodes brassicae (L.)	Brassica Whitefly	Aleyrodidae	Europe	Infest foliage
Bagrada spp.	Harlequin Bugs	Pentatomidae	Africa, India, S.E. Asia	Sap-suckers
Plutella xylostella (L.)	Diamond-back Moth	Yponomeutidae	Cosmopolitan	Larvae hole leaves
Pieris canidia (Sparr.)	Small White Butterfly	Pieridae	S.E. Asia, India	Larvae defoliate
Pieris rapae (L.)	Small White Butterfly	Pieridae	Europe, Asia	Larvae defoliate
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	Cosmopolitan	Larvae are cutworms
Agrotis segetum (D. & S.)	Common Cutworm	Noctuidae	Cosmopolitan in Old World	Larvae are cutworms
Delia brassicae (Bouché)	Cabbage Root Fly	Anthomyiidae	Europe, N. America	Larvae eat roots
Athalia spp.	Cabbage Sawflies	Tenthredinidae	Cosmopolitan	Larvae defoliate
Aulacophora similis (Ol.)	Red Melon Beetle	Chrysomelidae	Thailand	Adults eat leaves
Phyllotreta spp.	Cabbage Flea Beetles	Chrysomelidae	Cosmopolitan	Adults hole leaves
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
MINOR PESTS				
Acheta testaceus (Wlk.)	Field Cricket	Gryllidae	S.E. Asia	Roots & seedlings eaten
Gryllotalpa africana (Pal.)	African Mole Cricket	Gryllotalpidae	Old World	Roots & seedlings eaten
Myzus persicae (Sulz.)	Peach–Potato Aphid	Aphididae	Cosmopolitan	Infest shoots & leaves
Aphis gossypii Glov.	Cotton Aphid	Aphididae	S.E. Asia	Infest shoots & leaves
Eurydema pulchrum (Westw.)	Harlequin Bug	Pentatomidae	Laos, Philippines	Sap-sucker
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Pantropical	Sap-sucker; toxic saliva
Dysdercus spp.	Cotton Stainers	Pyrrhocoridae	Philippines	Sap-suckers
Bemisia inconspicua (Quaint.)	Whitefly	Aleyrodidae	Philippines	Infest leaves
Thrips angusticeps Uzel	Cabbage Thrips	Thripidae	Europe	Infest foliage
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Infest foliage
Hepialus spp.	Swift Moths	Hepialidae	Europe	Larvae eat roots
Pieris brassicae (L.)	Large White Butterfly	Pieridae	Europe, India, N. America	Larvae eat leaves
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	S.E. Asia	Larvae defoliate
Mamestra brassicae (L.)	Cabbage Moth	Noctuidae	Europe	Larvae defoliate
Trichoplusia ni (Hubner)	Cabbage Semi-looper	Noctuidae	S.E. Asia, USA	Larvae defoliate
Chrysodeixis chalcites (Esp.)	Cabbage Semi-looper	Noctuidae	Africa, Med., India, S.E. Asia Australasia, Japan	Larvae defoliate

(continued)

Plusia orichalcea (Hub.)	–	Noctuidae	S.E. Asia	Larvae defoliate
Spodoptera exigua (Hub.)	Beet Armyworm	Noctuidae	Thailand	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa, Med.	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India, S.E. Asia	Larvae defoliate
Spodoptera exempta (Wlk.)	African Armyworm	Noctuidae	Papua NG	Larvae defoliate
Spodoptera mauritia (Boisd.)	Paddy Armyworm	Noctuidae	S.E. Asia	Larvae defoliate
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	Old World	Larvae defoliate
Xestia c-nigrum (L.)	Spotted Cutworm	Noctuidae	Europe, Asia, N. America	Larvae defoliate
Crocidolomia binotalis (Zell.)	Cabbage Cluster-caterpillar	Pyralidae	Africa, India, S.E. Asia, Australia	Larvae defoliate
Hellula phidilealis Wlk.	Cabbage Webworm	Pyralidae	Sierra Leone, C. & S. America	Larvae defoliate
Hellula undalis (F.)	Oriental Cabbage Webworm	Pyralidae	N. & W. Africa, Near East, S.E. Asia, Australia, NZ	Larvae defoliate
Evergestis spp.	Cabbageworms	Pyralidae	Europe, USA	Larvae defoliate
Hymenia recurvalis	Cabbageworms	Pyralidae	Papua NG	Larvae defoliate
Tipula spp.	Leatherjackets	Tipulidae	Europe	Larvae eat roots
Phytomyza horticola Goureau	Pea Leaf Miner	Agromyzidae	Cosmopolitan in Old World	Larvae mine leaves
Phytomyza rufipes Meig.	Cabbage Leaf Miner	Agromyzidae	Europe	Larvae mine leaves
Phytomyza spp.	Leaf Miners	Agromyzidae	Asia	Larvae mine leaves
Liriomyza brassicae (Riley)	Cabbage Leaf Miner	Agromyzidae	Cosmopolitan	Larvae mine leaves
Contarinia nasturtii (Kieff.)	Swede Midge	Cecidomyiidae	Europe	Larvae gall shoot
Delia platura (Meign.)	Bean Seed Fly	Anthomyiidae	Cosmopolitan	Larvae destroy roots
Delia floralis (Fall.)	Turnip Root Fly	Anthomyiidae	Europe	Larvae bore stem
Meligethes aeneus Fab.	Blossom Beetle	Nitidulidae	Europe	Adults infest flowers
Phaedon spp.	Mustard Beetles	Chrysomelidae	Europe	Adults infest flowers
Psylliodes chrysocephala (L.)	Cabbage Stem Flea Beetle	Chrysomelidae	Europe	Larvae gall stems
Adoretus spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae eat roots
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae eat roots
Ceutorhynchus quadridens (Panz.)	Cabbage Stem Weevil	Curculionidae	Europe	Larvae gall stem
Ceutorhynchus assimilis (Payk.)	Cabbage Seed Weevil	Curculionidae	Europe	Larvae gall seeds
Ceutorhynchus pleurostigma (March.)	Turnip Gall Weevil	Curculionidae	Europe	Larvae gall root
Aperitmetus brunneus (Hust.)	Tea Root Weevil	Curculionidae	E. Africa	Larvae eat roots

BREADFRUIT (*Artocarpus altilis* – Moraceae)

A native of Polynesia, this is one of the most important food fruits in the world. It is now widespread in the tropics and particularly abundant in Polynesia as a staple food. Cultivation has been practised since antiquity and more than 100 varieties are known. A handsome tree, 15–20 m in height, bears prickly fruits the size of a melon in the leaf axils; technically the fruit is a syncarp. It is usually grown only for local consumption. The fruit is mostly starch in composition.

MAJOR PESTS				
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Philippines	Encrust leaves
Pseudococcus spp.	Mealybugs	Pseudococcidae	Philippines	Encrust leaves
MINOR PESTS				
Drosicha townsendi (Ckll.)	Giant Mealybug	Margarodidae	Philippines	Infest leaves
Icerya seychellarum (Westw.)	Seychelles Fluted Scale	Margarodidae	Philippines	Infest leaves
Chrysomphalum aonidum (L.)	Florida Red Scale	Diaspididae	Philippines	Infest leaves
Aspidiotus destructor Sing.	Coconut Scale	Diaspididae	S.E. Asia	Infest leaves
Aonidiella aurantii (Mask.)	California Red Scale	Diaspididae	Philippines	Infest leaves
Pulvinaria psidii Mask.	Green Shield Scale	Coccidae	Philippines	Infest leaves
Leptocorisa acuta (Thumb.)	Rice Bug	Coreidae	S.E. Asia	Sap-sucker; toxic saliva
Margaronia caesalis (Wlk.)	–	Pyralidae	Malaysia	Larvae eat leaves
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	Philippines	Larvae bore branches
Dacus umbrosus (F.)	Fruit Fly	Tephretidae	Philippines	Larvae bore fruit
Batocera rubus (L.)	White-spotted Longhorn	Cerambycidae	Philippines	Larvae bore branches
Xyleborus perforans (Woll.)	Coconut Shot-hole Borer	Scolytidae	Pantropical	Adults bore branches

CAPSICUMS (*Capsicum* spp. – Solanaceae) (= Sweet Peppers and Chilli)

The centre of origin is uncertain, but probably was Peru; they spread throughout the New World very early and are now grown widely throughout the tropics and sub-tropics, and under glass (or polythene) in temperate regions. They can be grown from sea-level to 2000 m or more in the tropics, preferably with a rainfall of 60–120 cm per annum. They are sensitive to frost, water-logging, and too much rain. In habit the plant is a very variable herb, erect, many-branched, and is grown as an annual. The main areas of production are India, Thailand, Indonesia, Japan, Mexico, Uganda, Kenya, Nigeria, and Sudan. Sweet peppers are large and green, turning red as they ripen, and are used in salads or cooked as vegetables. Chillies are small, pungent, and bright red, used in curries or dried to make cayenne pepper and paprika. (See also Butani, 1976*c*).

MAJOR PESTS				
Aphis gossypii Glover	Melon/Cotton Aphid	Aphididae	Cosmopolitan	Infest leaves & stems
Myzus persicae (Sulz.)	Peach–Potato Aphid	Aphididae	Cosmopolitan	Infest leaves & stems
Epicauta albovittata (Gestro)	Striped Blister Beetle	Meloidae	E. Africa, Somalia	Adults defoliate
Epilachna spp.	Epilachna Beetles	Coccinellidae	S.E. Asia	Leaves eaten
Helicoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	S.E. Asia, India	Larvae bore fruits
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Cosmopolitan	Leaves scarified
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	Pantropical	Leaves scarified
MINOR PESTS				
Brachytrupes portentosus Licht.	Large Brown Cricket	Gryllidae	India	Leaves attacked
Gryllotalpa orientalis (Pal.)	Asian Mole Cricket	Gryllotalpidae	S.E. Asia	Eat roots
Hodotermes mossambicus Hag.	Harvester Termite	Hodotermitidae	S. & E. Africa	Destroy plant
Empoasca spp.	Green Leafhoppers	Cicadellidae	S.E. Asia	Sap-suckers on foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	S.E. Asia, India	Encrust foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	India	Infest foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Infest foliage
Bemisia tabaci (Genn.)	Cotton Whitefly	Aleyrodidae	S.E. Asia, India	Infest foliage
Cyrtopeltis tenuis Reuter	Tomato Mirid	Miridae	Philippines	Sap-sucker; toxic saliva
Helopeltis theobromae (Miller)	Cocoa Capsid	Miridae	Malaysia	Sap-sucker; toxic saliva
Helopeltis westwoodi White	Capsid Bug	Miridae	Africa	Sap-sucker; toxic saliva
Helopeltis schoutedeni Reuter	Cotton Jassid	Miridae	Africa	
Acanthocoris spp.	Coreid Bugs	Coreidae	Philippines	Sap-suckers; toxic saliva
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Infest foliage
Scirtothrips dorsalis Hood	Chilli Thrips	Thripidae	India, Sri Lanka, Thailand, Australia, China, Japan	Infest foliage; virus vector
Symmetrischema capsica	Pepper Flower Bud Moth	Tortricidae	Trinidad	Larvae bore buds
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	S.E. Asia, India	Larvae are cutworms
Spodoptera exigua (Hub.)	Beet Armyworm	Noctuidae	India	Larvae bore fruits
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Malaysia, Laos, Philippines, India	Larvae bore fruits
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Triacola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia	Larvae eat leaves or bore fruits
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	Philippines	Larvae eat leaves or bore fruits
Mythimna spp.	Rice Cutworms	Noctuidae	S.E. Asia	Larvae eat leaves or bore fruits (both)
Plusia spp.	Semi-loopers	Noctuidae	India	
Agrius convolvuli (L.)	Convolvulus Hawk	Sphingidae	S.E. Asia	Larvae defoliate
Dacus spp.	Fruit Flies	Tephretidae	S.E. Asia	Larvae inside fruit

(continued)

Asphondylia capsici Barnes	Capsicum Gall Midge	Cecidomyiidae	Med.	Larvae gall fruit
Anomala spp.	White Grubs	Scarabaeidae	Philippines, India	Larvae eat roots
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Psylliodes spp.	Flea Beetles	Chrysomelidae	Philippines	Adults hole leaves
Orthaulaca similis Oliv.	Leaf Beetle	Chrysomelidae	Philippines	Adults eat leaves
Monolepta signata Oliv.	Leaf Beetle	Chrysomelidae	India	Adults eat leaves
Tarsonemus translucens Green	Leaf Mite	Tarsonemidae	India	Scarify foliage
Calacarus carinatus (Green)	Purple Mite	Eriophyidae	India, Japan, S.E. Asia, S. USA, Australia	Distort foliage

CARDAMOM (*Elettaria cardamomum* – Zingiberaceae)

A native of India, but now grown in other tropical countries, especially C. America. It is a perennial herb 2–4 m in height, with white flowers and thin triangular fruits (capsules) containing the small pale seeds. The seeds are used in curries, pickles, cakes and other culinary purposes, as a masticatory in India, and for medicinal purposes.

MAJOR PESTS				
Ragwelellus horvathi Popp.	Cardamom Capsid	Miridae	Papua NG	Sap-sucker
Sciothrips cardamomi (Ramk.)	Cardamom Thrips	Thripidae	India, Papua NG	Infest foliage
Lenodera vittata Wlk.	Leaf Caterpillar	Lasiocampidae	India	Larvae eat leaves
Eupterote spp.	Hairy Caterpillars	Bomby cidae	India	Larvae eat leaves
MINOR PESTS				
Orthacris sp.	Leaf Grasshopper	Acrididae	India	Eat young leaves
Pentalonia nigronervosa Coq.	Banana Aphid	Aphididae	India	Infest leaf bases
Aphrophora nuwarana Dist.	Spittle Bug	Cercopidae	India	Suck sap
Tettigoniella ferruginea	Leafhopper	Cicadellidae	India	Infest young leaves
Diaspis spp.	Armoured Scales	Diaspididae	India	Encrust foliage
Mittilaspis spp.	Soft Scales	Coccidae	India	Encrust berries
Stephanitis typica Dist.	Banana Lace Bug	Tingidae	India, S.E. Asia, Papua NG	Sap-sucker; toxic saliva
Riptortus pedestris F.	Coreid Bug	Coreidae	India	Sap-sucker
Leewania maculans P. & S.	Thrips	Thripidae	India	Infest foliage
Dichocrocis punctiferalis (Guen.)	Castor Capsule Borer	Pyralidae	India	Larvae bore shoots capsules
Hilarographa caminodes Meyr.	–	Plutellidae	India	Larvae eat leaves
Acanthopsyche bispar Wlk.	Bagworm	Psychidae	India	Larvae eat leaves
Homona sp.	Tortrix Moth	Tortricidae	India	Larvae roll leaves
Eumelia rosalia Cram.	Looper Caterpillar	Geometridae	India	Larvae defoliate
Attacus atlas L.	Atlas Moth	Saturniidae	India	Larvae defoliate
Plesioneura alysos M.	Black Skipper	Hesperiidae	India	Larvae fold leaves
Lampides elpis Godt.	Blue Butterfly	Lycaenidae	India	Larvae eat flowers pods
Alphaea biguttata Wlk.	Cardamon Tiger Moth	Arctiidae	India	Larvae eat leaves
Euproctis lutifacia Hamp.	Tussock Moth	Lymantriidae	India	Larvae defoliate
Hallomyia cardamomi Nayer	Root Gall Midge	Cecidomyiidae	India	Larvae gall root
Formosina flavipes M.	Shoot Fly	Chloropidae	India	Larvae bore shoots
Oulema sp.	Leaf Beetle	Chrysomelidae	India	Larvae mine leaves; adults eat strips on leaves
Prodioctes haematicus Chev.	Rhizome Weevil	Curculionidae	India, Sri Lanka	Larvae in rhizome

CASHEW (*Anacardium occidentale* – Anacardiaceae)

Cashew originated in C. and S. America and the W. Indies, and was widely distributed by early Portuguese and Spanish adventurers. It was first brought to India from Brazil in the 16th century, and also reached Malaya and the E. African coast at about the same time. It is now naturalized in many tropical countries, particularly in coastal areas. The spreading evergreen tree, up to 12 m in height, is hardy and drought-resistant, and can be grown under varied conditions of climate and soil from sea-level to 1500 m with 40–350 cm of rain. It is easily damaged by frost. The fruit is a kidney-shaped nut partly embedded in a large fleshy pedicel (Cashew Apple). The main production areas are the coastal strips of S. India, Mozambique and Eastern Africa.

MAJOR PESTS				
Zonocerus variegatus	Elegant Grasshopper	Acrididae	E. Africa	Defoliate
Toxoptera odinae van d.G.	Mango Aphid	Aphididae	India	Infest foliage
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	Pantropical	Infest leaves
Helopeltis spp.	Helopeltis Bugs	Miridae	S.E. Asia, Africa	Toxic saliva
Helopeltis anacardii Miller	Cashew Helopeltis	Miridae	India, E. Africa	Toxic saliva
Indarbela tetraonis (Moore)	Bark Borer	Metarbelidae	India	Larvae eat bark
Macalla moncusalis Wlk.	Shoot Webber	Pyralidae	India	Larvae web & eat young leaves
Paranaleptes reticulata (Thom.)	Cashew Stem Girdler	Cerambycidae	E. Africa	Larva girdles stem
Rhytidodera simulans (White)	Cashew Longhorn	Cerambycidae	Malaysia	Larvae bore trunk
Plocoederus ferrugineus L.	Longhorn Beetle	Cerambycidae	India	Larvae bore trunk
Mecocorynus loripes Chevr.	Cashew Weevil	Curculionidae	E. Africa, Mozambique	Larvae bore under bark
Exiophyes rossettonis (K.)	Cashew Bud Mite	Eriophyidae	S. America	Infest buds
MINOR PESTS				
Aphis craccivora Koch	Groundnut Aphid	Aphididae	Cosmopolitan	Infest leaves
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest twigs
Coccus mangiferae (Green)	Mango Scale	Coccidae	Malawi }	Infest leaves
Pseudaonidia trilobitiformis (Green)	Tribolite Scale	Coccidae	Malawi }	Suck sap
Egropa malayensis (Dist.)	Treehopper	Membracidae	Malaysia	Infest twigs
Pseudotheraptus wayi Brown	Coconut Bug	Coreidae	E. Africa	Toxic saliva
Selenothrips rubrocinctus (Giard)	Red-banded Thrips	Thripidae	Philippines, India	Infest leaves
Attacus atlas (L.)	Atlas Moth	Saturniidae	Malaysia	Larvae defoliate
Orthaga incarusalis (Wlk.)	–	Pyralidae	Malaysia, India	Larvae web leaves
Euproctis spp.	Tussock Moths	Lymantriidae	Philippines	Larvae defoliate
Orgyia australis	Tussock Moth	Lymantriidae	Philippines	Larvae defoliate
Xylotrupes gideon (L.)	Unicorn Beetle	Scarabaeidae	Malaysia	Adults defoliate
Niphonoclea spp.	Twig Borers	Cerambycidae	Philippines	Larvae bore twigs
Plocoederus spp.	Longhorn Beetles	Cerambycidae	India	Larvae bore trunk
Sthenias grisator F.	Stem Girdler	Cerambycidae	India	Larvae girdle stem
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Atractocerus brevicoinis	Timberworm	Lymexyliodae	E. Africa	Larva bore trunk

CASSAVA (*Manihot esculenta* – Euphorbiaceae) (= Manioc; Tapioca; Yuca)

Cassava is unknown in the wild state; it probably originated from either S. Mexico or Brazil. It is a lowland tropical crop and can be grown under a variety of conditions, but favours a light sandy soil. It is a short-lived shrub, 1–5 m in height, with latex in all parts. The tubers develop as swellings on adventitious roots close to the stem, 5–10 per plant. The core is rich in starch (20–30%), also calcium and vitamin C. Cyanic acid is present in the tubers and has to be destroyed before the tubers are eaten. More is grown in Africa than elsewhere, and here it is for local consumption. Cassava is exported from Indonesia, Malaysia, Madagascar and Brazil. Propagation is by stem cuttings. (See also Bellotti & van Schoonhoven, 1978).

MAJOR PESTS				
Zonocerus elegans (Thun.)	Elegant Grasshopper	Acrididae	Africa	} Defoliate; strip bark
Zonocerus variegatus L.	Variegated Grasshopper	Acrididae	Africa	}
Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	Pantropical	Infest foliage; virus vector
Phenacoccus manitioti	Cassava Mealybug	Pseudacoccidae	S. America, Africa	}
Phenacoccas herveni	Cassava Mealybug		S. America	}
Aonidomytilus albus (Ckll.)	Cassava Scale	Diaspididae	Africa, India, Florida, C. & S. America	} Encrust stems
Erinnyis ello (L.)	Cassava Hornworm	Sphingidae	USA, C. & S. America	Larvae defoliate
Mononychellus tanajoa	Green Cassava Mite	Tetranychidae	S. America, Africa	Shoot infested / destroyed
MINOR PESTS				
Brachytrupes portentosus (Lich.)	Large Brown Cricket	Gryllidae	Papua NG	} Eat roots & cuttings
Gryllotalpa spp.	Mole Crickets	Gryllotalpidae	Africa, Asia	}
Coptotermes spp.	Subterranean Termites	Rhinotermitidae	Madagascar, S. America	Eat cuttings & hollow roots
Aleurotrachelus sp.	Whitefly	Aleyrodidae	USA, S. America	} Infest foliage; virus vectors
Bemisia spp.	Whiteflies	Aleyrodidae	Africa, Asia	}
Trialeurodes variabilis	Whitefly	Aleyrodidae	USA, S. America	}
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest leaves
Phenacoccus gossypii T. & C.	Mexican Mealybug	Pseudococcidae	S. America, Hawaii	Infest leaves; toxic; saliva
Planococcus citri (Risso)	Root Mealybug	Pseudococcidae	Pantropical	Infest leaves & roots
Coccus viridis (Green)	Soft Green Scale	Coccidae	Madagascar, Pacific Isl.	Infest leaves
Pseudaulacaspis pentagona (T.-T.)	White Peach Scale	Coccidae	Pacific Isl.	Encrust stems
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Cosmopolitan	Encrust stems
Saissetia nigra (Nietn.)	Nigra Scale	Coccidae	Malaysia, Pacific Isl.	Encrust stems
Vatiga manihotae	Cassava Lacebug	Tingidae	S. America	}
Amblypelta spp.	Leaf-footed Bugs	Coreidae	Solomon Isl., Papua NG	} Sap-suckers; toxic saliva; tatter young leaves
Dasynus manihotis	Cassava Bug	Coreidae	Papua NG	}
Helopeltis bergrothi Reut.	Mosquito Bug	Miridae	Africa	}
Leptoglossus australis (F.)	Squash Bug	Coreidae	S.E. Asia	}
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	S.E. Asia	}
Cystomenus bergi Froeschres	Root Bug	Cydnidae	S. America	Feed on roots
Scirtothrips manihoti Bondar	Cassava Thrips	Thripidae	C. & S. America	Infest foliage
Selenothrips rubrocinctus (Giard)	Red-banded Thrips	Thripidae	Pacific Isl.	Infest foliage
Atta spp.	Leaf-cutter Ants	Formicidae	S. America	Adults defoliate
Acromyrmex spp.	Leaf-cutter Ants	Formicidae	S. America	Adults defoliate
Zeuzera coffeae Niet.	Red Coffee Borer	Cossidae	Papua NG, Solomon Isl.	Larvae bore stems
Eldana saccharina Wlk.	Sugarcane Stalk Borer	Pyralidae	Africa	Larvae bore stems
Agrotis ipsilon (Wlk.)	Black Cutworm	Noctuidae	S.E. Asia, S. America	Larvae are cutworms eat bark of cuttings

(continued)

Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Madagascar	Larvae are cutworms
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia, Pacific Isl., Australasia	Larvae defoliate
Dasychira horsfieldi (Saund.)	Tussock Moth	Lymantriidae	Malaysia	Larvae defoliate
Jatrophobia brasiliensis Rubs.	Gall Midge	Cecidomyiidae	USA, S. America	Larvae gall young leaves
Anastrepha spp.	Fruit Flies	Tephritidae	S. America	Larvae bore fruits stems
Lonchaea spp.	Shoot Flies	Lonchaeidae	S. America	Larvae bore shoots
Silba pendula	Shoot Fly	Lonchaeidae	S. America	Larvae bore shoots
Atherigona spp.	Shoot Fly	Muscidae	Japan, Pacific Isl.	Larvae bore shoots
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae eat roots & bark of cuttings
Phyllophaga spp.	White Grubs	Scarabaeidae	S. America	Larvae eat roots & bark of cuttings
Lepidiota stigma F.	White Grubs	Scarabaeidae	Thailand, Papua NG	
Leucopholis rorida F.	White Grub	Scarabaeidae	Indonesia, Papua NG	
Lagochirus spp.	Longhorn Beetles	Cerambycidae	Indonesia, C & S. America	Larvae bore stems
Coelosternus spp.	Stem Weevils	Curculionidae	S. America	Larvae bore stems
Apirocaulus cornutus Pasc.	Leaf-eating Weevil	Curculionidae	Papua NG	Adults eat leaves
Hypomeces squamosus F.	Gold-dust Weevil	Curculionidae	Thailand, Laos	Adults eat leaves
Sepiomus sp.	Weevil	Curculionidae	Thailand	Adults eat leaves
Mononychellus tanajoa (Bondar)	Spider Mite	Tetranychidae	Uganda, S. America	Infest foliage & scarify leaves; defoliate
Oligonychus spp.	Spider Mites	Tetranychidae	Australia, Pacific Isl., S. America	
Tetranychus cinnabarinus (Boisd.)	Carmine Mite	Tetranychidae	Pantropical	

More than 15 species of mealybugs have been collected from wild and cultivated cassava in Central America (IITA, 1982).

CASTOR (*Ricinus communis* – Euphorbiaceae)

Castor grows wild in N. and E. Africa, Yemen, Near and Middle East, was established very early in Egypt, and from there was taken to India and China. Now it is cultivated in many tropical and sub-tropical countries. It needs a warm climate and 180 frost-free days. It is grown under a wide range of conditions of altitude and rainfall, but is killed by frost and waterlogged soil, or temperatures for any length of time over 30°C. It is an annual herb 1–7 m in height; sometimes a short-lived perennial. The main production areas are Brazil, India, Thailand, USA, Ecuador, S. Africa, Ethiopia, and Tanzania. The seeds contain copious endosperm with 40–55% oil content; the oil is used for medicinal purposes, and industrially in lubricants, soaps, inks, dyes, and for tanning. Propagation is by seed.

MAJOR PESTS				
Helopeltis schoutedeni Reut.	Cotton Helopeltis	Miridae	Africa	Sap-sucker; toxic saliva
Helopeltis spp.	Helopeltis Bugs	Miridae	S.E. Asia, Africa	Sap-suckers with toxic saliva
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan }	Sap-suckers with toxic saliva
Calidea spp.	Blue Bugs	Pentatomidae	Africa }	
Dichocrocis punctiferalis (Gn.)	Castor Capsule Borer	Pyralidae	India, SE Asia; Japan, Australia	Larvae bore capsules & shoots
Achaea spp.	Castor Semi-looper (Fruit-piercing Moth)	Noctuidae	Malaysia, India, Philippines, Africa Laos,	Larvae defoliate
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Africa	Larvae bore fruits
Xyleutes capensis (Wlk.)	Castor Stem Borer	Cossidae	E. Africa & C.	Larva bores stem
MINOR PESTS				
Gryllus spp.	Crickets	Grlyllidae	Africa, Asia }	Destroy seedlings
Gryllotalpa spp.	Mole Crickets	Gryllotalpidae	Africa, Asia }	
Several species	Grasshoppers	Acrididae	Asia, Africa	Destroy seedlings mostly
Zonocerus variegatus L.	Variegated Grasshopper	Acrididae	Africa	Defoliate
Empoasca formosana Paoli	Castor Jassid	Cicadellidae	S.E. Asia }	Sap-suckers, infest leaves; toxic saliva
Empoasca fascialis (Jacobi)	Cotton Jassid	Cicadellidae	Pantropical }	
Empoasca flavescens (F.)	Leaf-hopper	Cicadellidae	Malaysia }	
Ptyelus grossus F.	Spittlebug	Cercopidae	E. Africa	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Philippines	Infest stems
Bemisia spp.	Whiteflies	Aleyrodidae	Asia, Africa }	Sooty mould may be serious
Trialeurodes ricini	Whiteflies	Aleyrodidae	Asia }	
Aspidiotus destructor	Armoured Scale	Diaspididae	Africa & Asia }	Infest foliage
Aonid cells orientalis	Oriental Scale	Diaspididae	Pantropical }	
Euristylus capensis	Capsid Bug	Miridae	E. & S. Africa }	Sap-sucker; toxic saliva; feed on fruits
Taylorilygus ricini	Castor Capsid	Miridae	}	
Retithrips syriacus (Mayer)	Castor Thrips	Thripidae	India, Africa	Infest foliage
Maruca testulalis (Geyer)	Maruca Moth	Pyralidae	S.E. Asia	Larvae bore fruits
Ostsinia nubilatis	Corn Borer	Pyralidale	USA	Larval bore stems
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	S.E. Asia	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Helicoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	Old World Tropics	Larvae eat leaves
H. zea	American Bollworm	Noctuidae	NC & S America	Larvae eat leaves
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia	Larvae attack fruits

(continued)

Attacus ricini	Castor Silkworm	Saturniidae	Philippines	Larvae defoliate
Samia cynthia Druky	Lesser Atlas Moth	Saturniidae	China, SE Asia	Larvae defoliate
Euproctis varians (Wlk.) spp.	Tussock Moth	Lymantriidae	SE Asia	Larvae defoliate
Euproctis producta Wlk.	Tussock Moth	Lymantriidae	Africa, China	Larvae defoliate
Orgyia spp.	Tussock Moth	Lymantriidae	Asia, Africa	Larvae defoliate
Dasychira spp.	Tussock Moth	Lymantriidae	Philippines, Laos Africa	Larvae defoliate
Niphadolepis alianta Karsh	Jelly Grub	Limacodidae	Africa	Larvae defoliate
Parasa vivida (Wlk.)	Stinging Caterpillar	Limacodidae	Africa, India	Larvae defoliate
Latoia lepida (Wlk.)	Blue-striped Nettlegrub	Limacodidae	S.E. Asia, India	Larvae defoliate
Acrocercops conflua	Leaf Miner	Gracillariidae	Africa, Mozambique, Near East	Larvae mine leaves
Asphondylia ricini Mani	Castor Gall midge	Cecidomyiidae	India, Mozambique	Larvae gall fruits
Sphenoptera spp.	Jewel Beetles	Buprestidae	Africa	Larvae bore stems
Dihammus vastator Newm.	Longhorn Beetle	Cerambycidae	Philippines	Larvae bore stems
Hypomeces squamosus (F.) (Herbst.)	Gold-dust Weevil	Curculionidae	SE Asia	Adults eat leaves
Xyleborus fornicatus Eichh.	Tea Shot-hole Borer	Scolytidae	India, S.E. Asia	Adults bore stems
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	S. Africa, S.E. Asia	Scarify foliage
Oligonychus coffeae (Niet.)	Red Coffee Mite	Tetranychidae	Pantropical	Scarify foliage
Eutetranychus orientalis (Klein)	Oriental Mite	Tetranychidae	Africa, India	Scarify foliage
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	Pantropical	Scarify foliage
Tetranychus spp.	Red Spider Mites	Tetranychidae	Cosmopolitan	Scarify foliage

CHICKPEA (*Cicer arietinum* – Leguminosae) (= Gram; Garbanzo Bean)

Also called Gram, it is thought to have originated in western Asia, and has been the most important pulse crop of India since early times. Now cultivated widely throughout the tropics. A drought-resistant crop requiring a cool dry climate. It is grown in India as a winter crop; generally unsuccessful in the hot wet tropics. A spreading, branched annual herb, up to 0.5 m high, hairy, with short pods containing 1–2 seeds only Seeds vary in colour from white to red to black. Areas of maximum cultivation are India and the Middle East; the crop is grown largely for local consumption; India grows over 8 million hectares annually, producing 4–5 million tonnes. The foliage is, however, toxic and is not used for fodder.

MAJOR PESTS				
Tricentrus bicolor Dist.	Tree-hopper	Membracidae	India	Infest stems; suck sap
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	India	Larvae are cutworms
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	India	Larvae eat shoots; bore pods
Melanagromyza obtusa (Mall.)	Bean Pod Fly	Agromyzidae	India	Larvae bore young seeds in pod
Tanymecus indicus Fst.	Surface Weevil	Curculionidae	India	Adults cut stems of seedlings
MINOR PESTS				
Atractomorpha crenulata F.	Grasshopper	Acrididae	India	Adults & nymphs eat foliage
Bemisia tabaci Genn.	Cotton Whitefly	Aleyrodidae	India	Infest leaves
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	Infest foliage
Lamprosema indicata F.	Webworm	Pyralidae	India	Larvae web leaves
Agrotis segetum Schiff.	Common Cutworm	Noctuidae	India	Larvae are cutworms
Agrotis spp.	Cutworms	Noctuidae	India	Larvae are cutworms
Spodoptera exigua (Hb.)	Lesser Armyworm	Noctuidae	India	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India	Larvae defoliate
Plusia orichalcea (F.)	–	Noctuidae	India	Larvae defoliate
Mythimna loreyi (Dup.)	Rice Armyworm	Noctuidae	India	Larvae defoliate
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	India	Larvae defoliate
Lampides boeticus L.	Pea Blue Butterfly	Lycaenidae	India	Larvae inside pods

CINCHONA (*Cinchona* spp. – Rubiaceae) (= Quinine)

This is a small evergreen tree, or shrub, native to the Andes in S. America, and from the bark is extracted quinine, the specific remedy for the cure of malaria. The use of cinchona bark was known to the S. American Indians, and later to the Jesuits who were responsible for its introduction to the rest of the world and its widespread cultivation. It is now cultivated in India, Java, and E. Africa, in addition to S. America 40 spp. of *Cinchona* known but only four or five species and their hybrids are grown for quinine production, but two are probably only varieties.

MAJOR PESTS

Some of the species listed below occasionally do economic damage.

MINOR PESTS

Helopeltis antonii Sign.	Tea Mosquito Bug	Miridae	India, S.E. Asia	Sap-suckers; toxic saliva
Helopeltis bergrothi Reut.	Mosquito Bug	Miridae	Africa	
H. bradi Wat.	Mosquito Bug	Miridae	Indonesia	
Pachypeltis humeralis (W.)	Mirid Bug	Miridae	India	
Palpita marinata Hmps.	–	Pyralidae	Malaysia, SE Asia	Larvae eat leaves
Betippa laleana M.	Slug Caterpillar	Limacodidae	India	Larvae defoliate
Popillia chlorion N.	Flower Beetle	Scarabaeidae	India	Adults defoliate
Holotrichia repetita S.	Cockchafer	Scarabaeidae	India	Adults eat leaves
Rhizotrogus rufus A.	Cockchafer	Scarabaeidae	India	Adults eat leaves
Serica nilgiriensis S.	Cockchafer	Scarabaeidae	India	Adults eat leaves
Sympiezomias decipiens M.	Leaf Weevil	Curculionidae	India	Adults eat leaves
Xyleborus fornicatus Eichh.	Tea Shot-hole Borer	Scolytidae	India, S.E. Asia, Madagascar	Adults bore stems and twigs
Zeuzera coffeae	Red Coffee Borer	Cossidae	SE Asia	Larvae bore branches
Daphnis hypothous Cramer	Hawk Moth	Sphingidae	Malaysia	Larvae eat leaves
Dematodes spp.	Grey Weevil	Curculionidae	SE Asia, China	Adults eat leaves
Apoderus cinchonae Rpk.	Leaf-roll Weevil	Curculionidae	Indonesia	Adults eat foliage; ♀makes leafroll for larva.
Euproctis flexuosa (Sn.)	Cinchona Tussock Moth	Yumantriidae	S.E Asia	
Drygia postica Wlk.	Tussock Moth	Lymantriidae	S.E Asia	Larvae eat leaves

CINNAMON (*Cinnamomum zeylandicum* – Lauraceae)

Cinnamon is extracted from the young bark of a small evergreen tree with dark coriaceous aromatic leaves. Native to Sri Lanka, it is now cultivated in India, Burma, Malaya, Seychelles, and also the W. Indies and parts of S. America. The leaves and roots also produce oil but of different quality and generally inferior to the essential oil from the bark. A popular spice for food flavouring, and widely used in medicine.

MAJOR PESTS				
Pauropsylla depressa Crawford	Fig-leaf Psyllid	Psyllidae	India	Young shoots galled
Attacus atlas (L.)	Atlas Moth	Saturniidae	Malaysia	Larvae defoliate
MINOR PESTS				
Vinsonia stellifera Westw.	Star Scale	Coccidae	Seychelles	Infest leaves
Phyllocnistis chrysophthalina	Cinnamon Leaf Miner	Phyllocnistidae	India	Larvae mine leaves
Homona coffearia (Niet.)	Tea Tortrix	Tortricidae	Malaysia	Larvae roll leaves
Graphium sarpedon (L.)	Blue Triangle	Papilionides	SE Asia	Larvae eat leaves
Papilio sp.	Swallowtail Butterfly	Papilionidae	India	Larvae eat leaves
Dasychira mendosa (Hubn.)	Jute Hairy Caterpillar	Lymantriidae	India, Malaysia	Larvae defoliate
Asuta sagenaria Wllgr.	Woolly Bear	Arctüdae	E. Africa	Larvae eat leaves
Rhynchites lauracere Voss	Laurel Weevil	Curculionidae	Indonesia	Adults girdle young twigs by bark eating

CITRUS (*Citrus* spp. – Rutaceae) (Orange, Lemon, Lime, Mandarin, Tangerine, Grapefruit, Pomelo)

The cultivated species of *Citrus* are native to S.E. Asia, where they originated in the drier monsoon areas, but they are now grown throughout the tropics and sub-tropics, often under irrigation. They are thorny, aromatic shrubs or small trees with leathery evergreen leaves. The white or purple flowers are usually very fragrant. They are cultivated from about 15° N to 35° S, between sea-level and 1000 m, and are susceptible to frost unless the tree is dormant. Generally they require 100 cm of rain or else irrigation; they do not grow well in the very humid tropics. The main areas of production are in sub-tropical regions, and are S. USA, the Mediterranean region, S. Africa, C. America, Australia, China, and Japan. Although still a young industry in many places, it is now an exceedingly valuable one. (See also Butani, 1979*b*.)

MAJOR PESTS

Trioza erytreae (Del G.)	Citrus Psyllid	Psyllidae	E. & S. Africa	Nymphs pit leaves
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	Pantropical	Infest leaves
Dialeurodes citri (Ashm.)	Citrus Whitefly	Aleyrodidae	India, S.E. Asia	Infest leaves
Toxoptera aurantii (B. de F.)	Black Citrus Aphid	Aphididae	Cosmopolitan	Infest foliage
Toxoptera citricida (Kirk.)	Brown Citrus Aphid	Aphididae	Pantropical	Infest foliage
Planococcus citri (Ricco)	Root Mealybug	Pseudococcidae	Pantropical	Infest foliage
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	Pantropical	Infest foliage
Pseudococcus citriculus Green	Citrus Mealybug	Pseudococcidae	S.E. Asia	Infest foliage
Lepidosaphes beckii (Neumann)	Mussel Scale	Diaspididae	Cosmopolitan	Infest foliage
Aonidiella aurantii (Maskell)	California Red Scale	Diaspididae	Cosmopolitan	Infest foliage
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	Cosmopolitan	Infest foliage
C. dictyospesmi	Spanish Red Scale	Diaspididae	Cosmopolitan	Infest foliage
Saissetia oleae (Bern.)	Black Scale	Coccidae	Cosmopolitan	Infest foliage
Coccus viridis (Green)	Soft Green Scale	Coccidae	Pantropical	Infest foliage
Coccus alpinus De Lotto	Soft Green Scale	Coccidae	E. Africa	Infest foliage
Ceroplastes rubens Mask	Pink Waxy Scale	Coccidae	Old World tropics	Infest foliage
Gascardia destructor (Newst.)	White Waxy Scale	Coccidae	Africa, Australasia, Florida, Mexico	Infest foliage
Icerya purchasi Mask.	Cottony Cushion Scale	Margarodidae	Pantropical	Infest foliage
Rhynchocoris spp.	Citrus Green Bugs	Pentatomidae	Africa, Asia, China	Suck sap; toxic saliva
Heliothrips haemorrhoidalis (Bouché)	Black Tea Thrips	Thripidae	S.E. Asia	Scarify leaves
Scirtothrips aurantii Fauré	Citrus Thrips	Thripidae	Africa	Scar fruits
Papilio demoleus L.	Lemon Butterfly	Papilionidae	India, S.E. Asia, China, Australia	Larvae defoliate
Papilio demodocus Esp.	Orange Dog	Papilionidae	Africa	Larvae defoliate
Papilio polytes L.	Common Mormon	Papilionidae	S.E. Asia	Larvae defoliate
Othreis fullonia Cl.	Fruit-piercing Moth	Noctuidae	India, S.E. Asia, Australasia, China, Africa	Adults pierce fruits
Ceratitis capitata (Wied.)	Medfly	Tephritidae	Cosmopolitan	Larvae inside fruit
Ceratitis rosa Karsch	Natal Fruit Fly	Tephritidae	Africa	Larvae inside fruit
Dacus dorsalis (Hend.)	Oriental Fruit Fly	Tephritidae	S.E. Asia	Larvae in fruits
Solenopsis geminata (F.)	Fire Ant	Formicidae	India, S.E. Asia, Africa, C. & S. America	Sting workers
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Systates pollinosus Gerst.	Systates Weevil	Curculionidae	E. Africa	Adults eat leaves
Agrilus spp.	Citrus Bark Borers	Buprestidae	Philippines, India, China	Larvae bore bark
Anoplophora chinensis (Forst.)	Citrus Longhorn	Cerambycidae	China, Taiwan	Larvae bore trunk
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	Pantropical	Scarify leaves & fruit
Panonychus citri (Mc G.)	Citrus Red Spider Mite	Tetranychidae USA, S. America	S. Africa, Asia, Australia,	Scarify leaves & fruit

(continued)

Eutetranychus orientalis (Klein)	Oriental Mite	Tetranychidae	India, S.E. Asia, Africa, Taiwan	Scarify leaves & fruit
Aceria sheldoni (Ew.)	Citrus Bud Mite	Eriophyidae	Italy, Africa, USA, Australia	Feed on leaves and buds
Phyllocoptruta oleivora (Ashm.)	Citrus Rust Mite	Eriophyidae	Cosmopolitan	Feed on leaves and buds
Brevipalpus phoenicia (Geijskes)	Red Crevice Tea Mite	Tenuipalpidae	Pantropical	Feed on leaves and buds
MINOR PESTS				
Brachytrupes spp.	Large Brown Crickets	Gryllidae	Africa, Asia	Nursery pests
Nasutitermes spp.	Termites	Termitidae	S. America	Nursery pests
Diaphorina citri Kew.	Citrus Psyllid	Psyllidae	India, S.E. Asia, China, Japan	Vector of Green Virus
Aleurocanthus spiniferus Quaint	Orange Spiny Whitefly	Aleyrodidae	India, S.E. Asia, China, Japan	Infest leaves
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Philippines, Africa	Infest foliage
Aphis spiraecola Patch	Spiraea Aphid	Aphididae	Cosmopolitan	Infest foliage
Aphis tavaresi (Kirk.)	–	Aphididae	Malaysia	Infest foliage
Myzus persicae (Sulz.)	Green Peach Aphid	Aphididae	Philippines	Infest foliage
Coccus hesperidum L.	Brown Scale	Coccidae	Cosmopolitan	Infest foliage
Gascardia brevicauda (Hall)	White Waxy Scale	Coccidae	E. Africa	Encrust foliage
Chloropulvinaria psidii (Mask.)	Guava Scale	Coccidae	Pantropical	Infest foliage
Ceroplastes sinensis Del G.	Chinese Waxy Scale	Coccidae	Widespread	Encrust foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Cosmopolitan	Infest foliage
Pulvinaria spp.	Soft Scales	Coccidae	S.E. Asia	Infest foliage
Orthezia insignis Browne	Jacaranda Bug	Orthezidae	Africa, India, Malaysia, N., C. & S. America	Infest foliage
Vinsonia stellifera	Star Scale	Coccidae	Pantropical	Infest foliage
Drosicha stebbingii Stebb.	Giant Mealybug	Margarodidae	India, Pakistan	Infest foliage
Icerya seychellarum (Westw.)	Seychelles Fluted Scale	Margarodidae	S.E. Asia, Pan tropical	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Widespread	Infest foliage
Ricania speculum (Wlk.)	Black Planthopper	Ricaniidae	S.E. Asia	Infest twigs
Ricania sp.	Green Planthopper	Ricaniidae	S.E. Asia	Infest twigs
Tricentrus spp.	Treehoppers	Membracidae	Philippines, S. China	Infest twigs
Dictyophara sp.	–	Dictyopharidae	S. China	Infest foliage
Lepidosaphes gloverii (Packard)	Glover Scale	Diaspididae	S. America	Infest foliage
Aonidiella orientalis (Newst.)	Oriental Yellow Scale	Diaspididae	Pantropical	Infest foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Infest foliage
Pseudaonidia trilobitiformis (Green)	Trilobite Scale	Diaspididae	Pantropical	Infest foliage
Pinnaspis aspidistrae (Sign.)	Fern Scale	Diaspididae	Philippines	Infest foliage
Pinnaspis spp.	–	Diaspididae	Africa	Infest foliage
Parlatoria pergandii Comst.	Chaff Scale	Diaspididae	Pantropical	Infest foliage
Selanaspidus articulatus	–	Diaspididae	S. America	Infest foliage
Unaspis citri (Cmst.)	Citrus Snow Scale	Diaspididae	Pantropical	Infest foliage
Ischnaspis longirostris (Sign.)	Black Line Scale	Diaspididae	Pantropical	Infest foliage
Distantiella theobroma (Dist.)	Cocoa Capsid	Miridae	W. Africa	Sap-sucker; toxic saliva
Helopeltis collaris Stal	Capsid	Miridae	Philippines	Sap-sucker; toxic saliva
Leptoglossus spp.	Leaf-footed Plant Bugs	Coreidae	Pantropical	Sap-suckers; toxic saliva
Nezara viridula L.	Green Stink Bug	Pentatomidae	Pantropical	Sap-sucker; toxic saliva
Scirtothrips citri (Moulten)	Citrus Thrips	Thripidae	India, USA (California)	Scar fruits
Papilio spp. (10 + spp.)	Citrus Butterflies	Papilionidae	S.E. Asia, India, Africa, Americas	Larvae defoliate
Prays citri Mill	Citrus Flower Moth	Yponomeutidae	S. Europe, India, Malaysia, Philippines, Australasia	Larvae eat flowers
Prays endocarpa Meyr.	Citrus Rind Borer	Yponomeutidae	India, Indonesia	Larvae bore rind
Phyllocnistis citrella Stnt.	Citrus Leaf Miner	Phyllocnistidae	N.E. Africa, India, China, Japan, S.E. Asia	Larvae mine leaves
Indarbela spp.	Wood-borer Moths	Metarbelidae	India	Larvae eat bark
Paramyelois transitella (Wlk.)	Navel Orangeworm	Pyralidae	USA (California)	Larvae bore fruits

(continued)

Chilades lajus (Stoll)	Citrus Blue	Lycaenidae	S.E. Asia	Larvae defoliate
Metanstra hyrtaca (Cramer)	Grisly Citrus Caterpillar	Lasiocampidae	S.E. Asia	Larvae defoliate
Attacus atlas	Atlas moth	Saturniidae	S.E. Asia	Larvae defoliate
Spodoptera spp.	Cotton Leafworms	Noctuidae	Old World tropics	Larvae defoliate
Othreis spp.	Fruit Piercing Moths	Noctuidae	India, S.E. Asia	Adults pierce fruit
Achaea spp.	Fruit Piercing Moths	Noctuidae	Africa, Asia	Adults pierce fruit
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia	Larvae destroy fruit
Euproctis similis (Fuess.)	Tussock Moth	Lymantriidae	Europe, Asia	Larvae defoliate
Zaprionus multistriata	Citrus Fruit Fly	Drosophilidae	S.E. Asia, India	Larvae in fruit pulp
Dasyneura citri G. & P.	Citrus Blossom Midge	Cecidomyidae	India, China, Mediterranean	Larvae in flowers; distort fruits
Anastrepha ludens (Lw.)	Mexican Fruit Fly	Tephritidae	Mexico, C. America	Larvae in fruit
Dacus cucurbitae Coq.	Melon Fly	Tephritidae	Africa, Asia, Australasia	Larvae in fruit
Dacus spp.	Fruit Flies	Tephritidae	India	Larvae in fruit
Paradalaspis quinaria Bez.	Rhodesian Fruit Fly	Tephritidae	S. & N.W. Africa	Larvae in fruit
Tetradacus tsuneonis (Miyake)	Japanese Orange Fruit Fly	Tephritidae	Japan, China	Larvae in fruit
Vespa/Vespula spp.	Common Wasps	Vespidae	Cosmopolitan	Adults pierce ripe fruits
Atta spp.	Leaf-cutting Ants	Formicidae	C. & S. America	Adults cut leaves
Oecophylla spp.	Red Tree Ants	Formicidae	Africa, S.E. Asia, Australasia	Nest in foliage; attack workers
Anomala spp.	Flower Beetles	Scarabaeidae	India, S.E. Asia	} Adults eat leaves; larvae eat roots in soil; Nursery pests
Schizonycha spp.	Cockchafers	Scarabaeidae	India	
Apate monachus F.	Black Borer	Bostrychidae	Africa, W. Indies	Adults bore stems
Chrysochroa fulminans (F.)	Jewel Beetle	Buprestidae	Philippines	Larvae bore branches
Prodagricomela nigricollis	Citrus Flea Beetle	Chrysomelidae	S. China	Larvae mine leaf; adults skeletonize
Argopistes spp.	Citrus Flea Beetles	Chrysomelidae	S. China	Larvae mine leaves
Monochamus spp.	Citrus Longhorns	Cerambycidae	India, S.E. Asia	Larvae bore branches
Niphonoclea capito (Newm.)	Mango Twig Borer	Cerambycidae	Philippines	Larvae bore twigs
Pachnaeus litus	Weevil	Curculionidae	Cuba	Adults eat leaves
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	S.E. Asia	Adults eat leaves
Brevipalpus californicus (Banks)	–	Tenuipalpidae	Cosmopolitan	Scarify foliage
Polyphagotarsonemus latus (Banks)	Yellow Mite	Tarsonemidae	Pantropical	Scarify leaves

CLOVE (*Eugenia caryophyllus* – Myrtaceae) (= *Syzygium aromaticum*)

One of the earliest and most important of the spices; native to the Molucca Islands, but today it is grown in many tropical countries. Cloves are the unopened flower buds of a small evergreen tree of symmetrical shape. They are very aromatic and have widespread uses, both whole and ground, as a culinary spice, for flavouring, and in medicine. The essential oil has many medicinal and industrial uses. Zanzibar produces 90% of the total world output, and the other producing countries are Indonesia, Mauritius and the W. Indies.

MAJOR PESTS				
Saissetia eugeniae	Clove Scale	Coccidae	Zanzibar	Infest foliage
Xyleborus dedevigranulatus (Schedl.)	–	Scolytidae	Malaysia	Adults bore stems
MINOR PESTS				
Macrotermes bellicosus (Smeath)	War-like Termite	Termitidae	Zanzibar	Destroy seedlings
Aleurotuberculatus eugeniae (Corb.)	Clove Whitefly	Aleyrodidae	Malaysia	Infest foliage
Lecanium spp.	Soft Scales	Coccidae	S. India	Encrust foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Malaysia	Encrust foliage
Saissetia nigra (Nietn.)	Nigra Scale	Coccidae	India	Encrust foliage
Dasychira horsfieldi (Saund.)	Tussock Moth	Lymantriidae	Malaysia	Larvae defoliate
Oecophylla smaragdina F.	Red Tree Ant	Formicidae	Zanzibar	Nest in foliage; attack workers
Chelidonium brevicorne Schwarz	Longhorn Beetle	Cerambycidae	Malaya	Larvae bore trunk
Hexamitodera semivelutina Hell.	Longhorn Beetle	Cerambycidae	Indonesia	Larvae bore trunk
Nothopeus fasciatipennis Wat.	Blue Clove Borer	Cerambycidae	Indonesia	Larvae bore trunk

COCOA (*Theobroma cacao* – Sterculiaceae)

Cocoa originated in the evergreen forest of the Brazilian Andes, and has been cultivated there since early times. It was spread through the New World in the 16th century, and in the 18th the Spanish took it to S.E. Asia and W. Africa. It is a small tree of the lower forest strata, essentially tropical; most are grown within 10° of the equator. The beans are borne inside pods on the trunks and branches. The main production areas are Ghana, Nigeria, S. & C. America. W. Indies, New Guinea and Samoa. (See also Entwistle, 1972.)

MAJOR PESTS				
Toxoptera aurantii (B. de F.)	Black Citrus Aphid	Aphididae	Cosmopolitan	Infest foliage
Planococcus citri (Risso)	Root Mealybug	Pseudococcidae	Cosmopolitan	Infest foliage
Coccus viridis (Green)	Soft Green Scale	Coccidae	Pantropical	Infest foliage
Helopeltis schoutedeni Reuter	Cotton Helopeltis	Miridae	Africa	Sap-sucker; toxic saliva
Sahlbergella singularis Haglund	Cocoa Capsid	Miridae	W. & E. Africa	Sap-sucker; toxic saliva spot pods
Heliothrips haemorrhoidalis (Bouché)	Black Tea Thrips	Thripidae	Cosmopolitan	Scarify foliage
Eulophonotus myrmelon Feldr.	Cocoa Stem Borer	Cossidae	W. & E. Africa	Larvae bore stems
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	Philippines, Malaysia, Indonesia	Larvae bore stems
MINOR PESTS				
Zonocerus variegatus L.	Variegated Grasshopper	Acrididae	Africa	Defoliate
Macrotermes bellicosus (Smeath.)	War-like Termite	Termitidae	W. Africa	Workers eat bark
Empoasca fascialis (Jacobi)	Cotton Jassid	Cicadellidae	W. Africa	Infest foliage
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Philippines	Infest foliage
Mesohomotoma tessmanni Aulm.	Cocoa Psylla	Psyllidae	W. Africa	Nymphs in shoots
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage; virus vectors
Planococcoides njalensis (Laing)	Cocoa Mealybug	Pseudococcidae	Africa	
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	Pantropical	
Pseudococcus hispidus (Morr.)	Mealybug	Pseudococcidae	Malaysia	Infest foliage
Ricania speculum Wlk.	Black Planthopper	Ricaniidae	Philippines	Infest foliage
Lawana candida (F.)	Moth Bug	Flattidae	Philippines	
Colobesthes falcata Guér.	Cocoa Moth Bug	Flattidae	Malaysia	Infest foliage
Pulastya discolorata	Moth Bug	Flattidae	S.E. Asia	
Stictococcus sjostedti Ckll.	–	Diaspididae	W. Africa	Infest foliage
Pseudaonidia trilobitiformis (Green)	Trilobite Scale	Diaspididae	Pantropical	Infest foliage
Helopeltis theobromae (Miller)	Cocoa Helopeltis	Miridae	Malaysia, Indonesia, Philippines	Sap-sucker; toxic; saliva
Helopeltis bergrothi Rent.	Cocoa Mosquito Bug	Miridae	Tropical Africa	
Distantiella theobroma (Dist.)	Cocoa Capsid	Miridae	W. Africa	Sap-suckers; toxic
Bryocoropsis laticollis	Capsid Bug	Miridae	W. Africa	saliva causes pod spotting
Pseudotheraptus wayi Brown	Coconut Bug	Coreidae	E. Africa	Sap-sucker; toxic saliva
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	Old World tropics	Sap-sucker; toxic saliva
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan (Philippines)	Sap-sucker; toxic saliva
Bathycoelia thalassina	–	Pentatomidae	W. Africa	Sap-sucker; toxic saliva
Selenothrips rubrocinctus (Giard)	Red-banded Thrips	Thripidae	W. Africa, S.E. Asia, C. & S. America	Scarify foliage
Ceratitis capitata (Wied.)	Medfly	Tephritidae	Africa, Australia, C. & S. America	Larvae in pods
Pardalaspis punctata Wied.	Fruit Fly	Tephritidae	Africa	Larvae inside pods
Parasa vivida (Wlk.)	Stinging Caterpillar	Limacodidae	W. & E. Africa	Larvae defoliate

(continued)

Parasa lepida (Cram.)	Blue-striped Nettlegrub	Limacodidae	S.E. Asia	Larvae defoliate
Acrocercops cramerella Snell.	Cocoa Pod Borer	Gracillariidae	Africa, S.E. Asia	Larvae bore pods
Characoma stictograpta Hmps.	Pod Husk Borer	Noctuidae	W. Africa	Larvae bore pods
Earias biplaga Wlk.	Spiny Bollworm	Noctuidae	Africa	Larvae bore pods
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia	Larvae damage pods
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Asia, Australasia	Larvae defoliate
Achaea janata (L.)	Castor Semi-looper	Noctuidae	S.E. Asia	Larvae defoliate
Thecla spp.	Hairstreaks	Lycaenidae	S. America	Larvae eat leaves
Laspeyresia toocosma	–	Tortricidae	W. Africa	Larvae eat leaves
Homona coffearia Niet.)	Tea Tortrix	Tortricidae	Philippines	Larvae roll leaves
Kotochalia junodi (Heyl.)	Bagworm	Psychidae	Africa	Larvae defoliate
Cryptothelea spp.	Bagworms	Psychidae	S.E. Asia	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantrüdae	Africa, India, S.E. Asia	Larvae eat leaves
Orygia spp.	Tussock Moths	Lymantaüdae	Africa, India, S.E. Asia	
Anomala spp.	White Grubs	Scarabaeidae	Philippines, Malaysia	Adults eat edges of leaves; larvae eat roots in soil
Apogonia cribricollis (Burm.)	White Grub	Scarabaeidae	Malaysia	
Leucopholis spp.	White Grubs	Scarabaeidae	Philippines	
Ootheca mutabilis (Sahlb.)	Brown Leaf Beetle	Chrysomelidae	Africa	Adults eat leaves
Apate monachus F.	Black Borer	Bostrychidae	Africa	Adult bore stems
Xylosandrus compactus (Eichh.)	Black Twig Borer	Scolytidae	Africa, India, S.E. Asia	Adults bore twigs
Xyleborus ferrugineus (F.)	Black Twig Borer	Scolytidae	Africa, S.E. Asia, N., C. & S. America	Adults bore twigs
Xyleborus similis (Ferr.)	Black Twig Borer	Scolytidae	Malaysia	Adults bore twigs
Xyleborus fornicatus Eichh.	Tea Shot-hole Borer	Scolytidae	Inida, S.E. Asia	Adults bore twigs
Chrysochroa spp.	Jewel Beetles	Buprestidae	Philippines	Larvae bore stems
Niphonoclea spp.	Twig Borers	Cerambycidae	Philippines	Larvae bore stems
Mallodon downesi F.	Stem Borer	Cerambycidae	Africa	Larvae bore stems
Steirastoma breve Guby	Cocoa Longhorn	Cerambycidae	C. & S. America	Larvae bore stems
Systates spp.	Systates Weevils	Curculionidae	Africa	Adults eat leaves

COCONUT (*Cocos nucifera* – Palmae)

Owing to the normal method of seed dispersal being by sea, the centre of origin of the coconut is uncertain; it has been abundant in the Old World and the Americas since early times, and is now typical of tropical coasts. It is confined to the tropics and is only successful if grown in the lowlands just above sea-level. The trees are tall, being up to 30 m in height, with a slender, often curved, trunk. Fruit-bearing starts after six years. The endosperm of the nut is dried to make copra from which oil is extracted. Propagation is from fruits planted in nurseries. The main production areas are the Philippines, Indonesia, India, New Guinea and the Pacific Islands. (See also Lever, 1969.)

MAJOR PESTS				
Pseudotheraptus wayi Brown	Coconut Bug	Coreidae	E. Africa	Sap-sucker; toxic saliva; cause nutfall
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Encrust leaves & fruits
Ischnaspis longirostris (Sign.)	Black Line Scale	Diaspididae	Pantropical	
Artona catoxantha (Hmps.)	Coconut Leaf Skeletonizer	Zygaenidae	S.E. Asia	Larvae skeletonize leaves
Oryctes boas (F.)	Rhinoceros Beetle	Scarabaeidae	Africa	
Oryctes rhinoceros L.	Rhinoceros Beetle	Scarabaeidae	India, S.E. Asia, Pacific	Adults eat crown; larvae live in rotting vegetation
Oryctes monoceros (Ol.)	Rhinoceros Beetle	Scarabaeidae	Africa	
Scapanes australis Arrow	Taro Beetle	Scarabaeidae	Moluccas	Adults bore shoot & stem
Brontispa spp.	Coconut Hispids	Chrysomelidae	S.E. Asia, Pacific	Adults & larvae eat Leaves
Diocalandra taitense (Gucr.)	Tahiti Coconut Weevil	Curculionidae	New Guinea, Solomon Isl., Madagascar	Larvae bore leaves & fruit stalks
Diocalandra frumenti (F.)	Four-spotted Coconut Weevil	Curculionidae	S.E. Asia, India, Africa, Australasia	Larvae bore leaves & fruit
Rhynchophorus ferrugineus (Oliv.)	Asiatic Palm Weevil	Curculionidae	S.E. Asia, India, Australia	Larvae bore into crown and trunk; crown may be destroyed
Rhynchophorus phoenicis (F.)	African Palm Weevil	Curculionidae	Africa	
Rhynchophorus palmarum (L.)	South American Palm Weevil	Curculionidae	C. & S. America	
MINOR PESTS				
Sexava spp.	Longhorned Grasshoppers	Tettigoniidae	New Guinea, Celebes	Defoliation by adults & nymphs
Locusta migratoria spp.	Migratory Locusts	Acrididae	Africa, India, Asia	Defoliation by adults & nymphs
Tropidacris spp.	–	Acrididae	C. & S. America	Defoliate
Aularches miliaris L.	Spotted Grasshopper	Acrididae	Thailand	Defoliation by adults & nymphs
Odontotermes spp.	Scavenging Termites	Termitidae	India, Mozambique	Nest on trunks & in ground
Macrotermes bellicosus	War-like Termite	Termitidae	E. Africa	Damage trunk
Nasutitermes spp.	–	Termitidae	S.E. Asia	Nest on trunks & in ground
Coptotermes spp.	Moist-wood Termites	Rhinotermitidae	S.E. Asia	Nest on trunks & in ground
Microcerotermes spp.	Live-wood Termites	Termitidae	S.E. Asia, Pacific	Nest on trunks & in ground
Graeffea spp.	Stick Insects	Phasmidae	Polynesia, Melanesia, Fiji, Samoa	Defoliate

(continued)

Aleurodicus destructor Quaint	Coconut Whitefly	Aleyrodidae	Indonesia, Malaysia, Philippines	Infest foliage
Cerataphis variabilis H.R.L.	–	Aphididae	E. Africa, Hawaii, Pacific, C. & S. America	Infest foliage
Pinnaspis buxi (Bch.)	–	Diaspididae	Pantropical	Infest foliage & fruits
Aonidiella orientalis (Newst.)	Oriental Yellow Scale	Diaspididae	Pantropical	Infest foliage & fruits
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	Pantropical	Infest foliage & fruits
Chrysomphalus dictyospermi (Morg.)	Spanish Red Scale	Diaspididae	Pantropical	Infest foliage & fruits
Pseudaonidia trilobitiformis (Green)	Trilobite Scale	Diaspididae	Pantropical	Infest foliage & fruits
Hemiberlesia palmae (Ckll.)	Palm Scale	Coccidae	Pantropical	Infest foliage & fruits
Vinsonia stellifera Westw.	Star Scale	Coccidae	E. Africa, Seychelles, India, S. America	Encrust leaves
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	Pantropical	Infest foliage & fruits
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	Pantropical	Infest foliage & fruits
Icerya seychellarum (West.)	Seychelles Fluted Scale	Margarodidae	Philippines	Infest foliage & fruits
Amblypelta cocophaga China	Coconut Bug	Coreidae	Solomon Isl.,	Sap-sucker; toxic saliva
Axiagastus campbelli Dist.	Shield Bug	Pentatomidae	Papua NG, Solomon Isl.	Sap-sucker; toxic saliva
Stephanitis typica (Dist.)	Lace Bug	Tingidae	S.E. Asia, India,	Sap-sucker; toxic saliva
Acritocera negligens	Spathe Borer	Cossidae	Fiji	Larvae bore spathe
Erionota thrax L.	Banana Skipper	Hesperiidae	Thailand, Philippines	Larvae cut & roll leaves
Gangara thyrsis (F.)	–	Hesperiidae	India, S.E. Asia, Japan	Larvae roll leaves
Hidari irava Moore	Leafbinder	Hesperiidae	S.E. Asia	Larvae bind leaves
Lotongus calathus How	Leafbinder	Hesperiidae	Thailand	Larvae bind leaves
Telicota palmarum Moore	Coconut Skipper	Hesperiidae	India, S.E. Asia	Larvae bind leaves
Batrachedra arenosella Wlk.	–	Cosmopterygidae	India, S.E. Asia, Australasia, Zaire, Guiana	Larvae damage flowers Prey on Coccoidea
Nephantis serinopa Meyr.	Black-headed Caterpillar	Xyloryctidae	India, Burma	Larvae defoliate
Tirabatha spp.	Flower-eating Caterpillars Australasia	Pyralidae	Thailand, Pacific,	Larvae feed on flowers
Setora nitens (Wlk.)	Nettlegrub	Limacodidae	S.E. Asia	Larvae defoliate
Latoia lepida (Cram.)	Nettlegrub	Limacodidae	S.E. Asia	Larvae defoliate
Thosea sinensis Wlk.	Nettle Caterpillar	Limacodidae	Thailand, Laos	Larvae defoliate
Amathusia phidippus L.	Palm Butterfly	Nymphalidae	Malaysia	Larvae defoliate
Castnia spp.	Giant Stalk Borers	Castniidae	C. & S. America	Larvae bore trunk
Mahasena corbetti Tams	Bagworm	Psychidae	S.E. Asia	Larvae eat leaves
Dasychira horsfieldi Saund.	Tussock Moth	Lymantriidae	Thailand	Larvae eat leaves
Oecophylla smaragdina Wlk.	Red Tree Ant	Formicidae	S.E. Asia	Attack workers
Plesispa reichei Chapuis	Coconut Hispid	Chrysomelidae	S.E. Asia	Larvae mine leaves
Promecotheca spp.	Coconut Leaf Miners	Chrysomelidae	S.E. Asia, Pacific	Larvae mine leaves
Coelaenomenodera elaeidis Wlk.	Oil Palm Leaf Miner	Chrysomelidae	W. & C. Africa	Larvae mine leaves; adults attack crown
Scapanes spp.	–	Scarabaeidae	Papua NG, Solomon Isl.	Adults eat foliage
Xylotrupes gideon (L.)	Unicorn Beetle	Scarabaeidae	S.E. Asia	Adults eat foliage
Papuana laevipennis Arrow	Taro Beetle	Scarabaeidae	Moluccas, Soiomons Papua NG	Adults eat foliage
Xyleborus ferrugineus (F.)	Shot-hole Borer	Scolytidae	Pantropical	Adults bore trunk
Xyleborus perforans (Woll.)	Coconut Shot-hole Borer	Scolytidae	Pantropical	Adults bore trunk
Melittomma insulare Fairm.	–	Lymexylidae	Madagascar, Seychelles	Larvae bore trunk base
Rhynchophorus vulneratus (Panzer)	Asiatic Palm Weevil	Curculionidae	Thailand	Larvae bore crown
Rhina afzelii Fhs.	–	Curculionidae	Africa, Madagascar	Larvae bore trunk
Rhina barbirostris F.	Bearded Weevil	Curculionidae	Mexico, Trinidad, S. America	Larvae bore trunk
Raoiella indica Hirst.	Date Palm Scarlet Mite	Tenuipalpidae	India, Egypt, Mauritius	Infest foliage
Aceria guerreronis Keifer	–	Eriophyidae	Colombia	Infest foliage

Lepesme (1947) listed 751 insect species recorded on *Cocos*, of which 22% are specific to coconut.

COCOYAM *(Xanthosoma sagittifolium* – Araceae) (= Tannia)

This is a native of the New World, cultivated there in tropical rain forest regions in pre-Columbian times, and only quite recently has been spread throughout the wet tropics; for example it was introduced into Ghana in 1841. Because of its resemblance to *Colocasia* it was called 'Cocoyam', and is sometimes distinguished by the name of 'New Cocoyam', but it is sometimes called 'Taro' also. It is a typical aroid in that it is a robust herb growing out from underground corms in height up to 2 m or more, but the leaves are sagittate and sharply pointed, which distingushes the plant from *Colocasia*. The food base consists of starch grains in the corm, but the grains are distinctly larger than those in Taro.

MAJOR PESTS

MINOR PESTS

Pentalonia nigronervosa Coq.	Banana Aphid	Aphididae	Pantropical	Infest foliage
Ligyrus ebenus (De G.)	–	Scarabaeidae	W. Indies	Larvae damage tubers
Araecerus fasciculatus (De Geer)	Coffee Bean Weevil	Brenthidae	USA	Attack tubers in stores mostly

COFFEE (*Coffea arabica & C. robusta* – Rubiaceae)

Arabica coffee originated in Ethiopia in forests at about 1500 to 2000 m, and was early taken to Arabia. It was introduced into Java in the late 17th century, to India and Ceylon at about the same time, and to E. Africa in the late 19th century. The crop is now widely grown throughout the tropics.

Robusta coffee grows wild in African equatorial forests, and is also now widely distributed throughout the tropics. This species is more successful at lower altitudes than is *arabica*, and is the more important species in Asia and tropical Africa. Both are evergreen shrubs or small trees, growing to 5 m if unpruned, bearing continuous clusters of berries along the smaller branches, crimson when ripe. The main production areas are Brazil, Java, Kenya, W. Indies, and several other S. American countries. (See also Le Pelley, 1968.)

MAJOR PESTS

Planococcus citri (Risso)	Root Mealybug	Pseudococcidae	Pantropical	Encrust roots mainly
Planococcus kenyae (Le Pelley)	Kenya Mealybug	Pseudococcidae	E. & W. Africa	Encrust foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Encrust foliage
Pseudococcus sp.	Root Mealybug	Pseudococcidae	S. America	Encrust roots
Asterolecanium coffeae Newstead	Star Scale	Asterolecanidae	E. Africa, Zaïre	Encrust branches
Gascardia brevicauda (Hall)	White Waxy Scale	Coccidae	E. Africa	Encrust foliage
Coccus alpinus De Lotto	Soft Green Scale	Coccidae	E. Africa	Infest foliage
Coccus viridis (Green)	Soft Green Scale	Coccidae	Pantropical	Infest foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Cosmopolitan	Infest foliage
Orthezia insignis Browne	Jacaranda Bug	Orthezidae	Africa, S. America	Infest foliage
Antestiopsis spp.	Antestia Bugs	Pentatomidae	Africa	Sap-suckers; toxic saliva
Lamprocapsidea coffeae (China)	Coffee Capsid	Miridae	E. Africa, Zaïre	Sap-suckers; toxic saliva
Habrochila ghesquierei Schout.	Coffee Lace Bug	Tingidae	E. Africa, Zaïre }	Sap-suckers; toxic saliva
Habrochila placida Hory.	Coffee Lace Bug	Tingidae	E. Africa, Zaïre }	
Hoplandothrips marshalli Karny	Coffee Leaf-rolling Thrips	Phlaeothripidae	Uganda	Cause leaf-rolling
Diarthrothrips coffeae Williams	Coffee Thrips	Thripidae	Africa	Scarify foliage
Parasa vivida (Wlk.)	Stinging Caterpillar	Limacodidae	Africa	Larvae defoliate
Parasa lepida (Cram.)	Blue-striped Nettlegrub	Limacodidae	Philippines	Larvae defoliate
Thosea sinensis (Wlk.)	Slug Caterpillar	Limacodidae	Philippines	Larvae defoliate
Niphadolepis alianta Karsch	Jelly Grub	Limacodidae	E. Africa, Malawi	Larvae defoliate
Eucosma nereidopa Meyr.	Coffee Tip Borer	Tortricidae	Kenya	Larvae bore shoots
Leucoptera spp.	Coffee Leaf Miners	Gracillariidae	Africa, S. America	Larvae mine leaves
Prophantis smaragdina Butler	Coffee Berry Moth	Pyralidae	Africa	Larvae web berries
Virachola bimaculata (Hew.)	Coffee Berry Butterfly	Lycaenidae	W. & E. Africa	Larvae bore berries
Epicampoptera marantica Tams	Tailed Caterpillar	Drepanidae	Tanzania, Zaïre	Larvae defoliate
Epicampoptera andersoni Tams	Tailed Caterpillar	Drepanidae	Kenya, Uganda, Nigeria	Larvae defoliate
Ascotis selenaria (Wlk.)	Coffee Looper	Geometridae	E. & S. Africa	Larvae defoliate
Leucoplema dohertyi (Warr.)	Leaf Skeletonizer	Epiplemidae	E. Africa, Zaïre	Larvae skeletonize leaves
Ceratitis coffeae (Bezzi)	Coffee Fruit Fly	Tephritidae	E. & W. Africa, Zaïre	Larvae inside fruits
Macromischoides aculeatus Mayr	Biting Ant	Formicidae	Uganda, Zaïre, Tanzania	Nest in foliage; attack workers
Gonocephalum simplex (F.)	Dusty Brown Beetle	Tenebrionidae	Africa	Adults eat bark
Anthores leuconotus (Ol.)	White Coffee Borer	Cerambycidae	E. Africa	Larvae bore stems
Dirphya nigricornis (Ol.)	Yellow-headed Borer	Cerambycidae	E. Africa	Larvae bore stems
Hypothenemus hampei (Ferr.)	Coffee Berry Borer	Scolytidae	Africa, S.E. Asia, S. America	Adults bore berries
Apate monachus F.	Black Borer	Bostrychidae }	Africa, Med., C. & S. America	Adults bore branches
Apate indistincta Murray	Black Borer	Bostrychidae }		
Systates pollinosus Gerst.	Systates Weevil	Curculionidae	E. Africa	Adults eat leaves
Oligonychus coffeae (Nietn.)	Red Coffee Mite	Tetranychidae	Pantropical	Scarify foliage

MINOR PESTS				
Zonocerus variegatus L.	Variegated Grasshopper	Acrididae	Africa	Defoliate
Bothrogonia sp.	Leafhopper	Cicadellidae	Philippines	Infest foliage
Aleurothrix floccosus (Mask.)	–	Aleyrodidae	S. America	Infest foliage
Dialeurodes citri (Ashm.)	Citrus Whitefly	Aleyrodidae	S.E. Asia, S. America	Infest foliage
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	S. America	Infest foliage
Toxoptera aurantii (B. de F.)	Black Citrus Aphid	Aphididae	Cosmopolitan	Infest foliage
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	Pantropical	Infest foliage
Geococcus coffeae Green	Coffee Root Mealybug	Pseudococcidae	Pantropical	Infest roots
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	Pantropical	Infest foliage
Cerococcus spp.	Soft Scales	Coccidae	Africa, Philippines, S. America	Infest foliage
Saissetia nigra (Nietn.)	Nigra Scale	Coccidae	Philippines	Infest foliage
Saissetia oleae (Bern.)	Black Scale	Coccidae	S. America	Infest foliage
Gascardia destructor (Newst.)	White Waxy Scale	Coccidae	Africa, Papua NG	Infest foliage
Ceroplastes rubens Mask.	Pink Waxy Scale	Coccidae	E. Africa, Asia	Infest foliage
Pseudaonidia trilobitiformis (Green)	Trilobite Scale	Diaspididae	Pantropical	Encrust foliage
Ischnaspis longirostris (Sign.)	Black Line Scale	Diaspididae	Africa, S.E. Asia, C. & S America	Encrust foliage
Selanaspidus articulatus (Morg.)	West Indian Red scale	Diaspididae	Pantropical	Encrust foliage
Lawana candida F.	Coffee Moth Bug	Flattidae	Indonesia, Java, Vietnam, Philippines	Infest foliage
Ricania speculum (Wlk.)	Black Planthopper	Ricaniidae	Philippines	Infest foliage
Leptoglossus australis F.	Leaf-footed Plant Bug	Coreidae	Africa, Asia	Sap-sucker; toxic saliva
Anoplocnemis curvipes F.	Coreid Bug	Coreidae	Africa	Sap-sucker; toxic saliva
Frankliniella schulzei (Trybom)	Cotton Flower Thrips	Thripidae	E. Africa, Sudan	Infest flowers
Heliothrips haemorrhoidalis (Bouche)	Black Tea Thrips	Thripidae	Pantropical	Infest foliage
Taeniothrips sjostedti (Trybom)	Bean Flower Thrips	Thripidae	Africa	Infest flowers
Selenothrips rubrocinctus (Giard)	Red-banded Thrips	Thripidae	Philippines	Infest foliage
Tropicomyza flacourtiae (Segny.)	Coffee Leaf Miner	Agromyzidae	Africa, India, Java, Papua NG	Larvae mine leaves
Ceratitis capitata (Wied.)	Medfly	Tephritidae	Africa, Hawaii, S. America	Larvae in berries
Ceratitis rosa (Ksh.)	Natal Fruit Fly	Tephritidae	E. Africa	Larvae in berries
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	Philippines	Larvae in berries
Atta spp.	Leaf-cutting Ants	Formicidae	S. & C. America	Adults defoliate
Xyleutes spp.	Stem Borers	Cossidae	Africa, S. USA, C. America, India	Larvae bore stems
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	Indonesia, Thailand, Malaysia, Philippines	Larvae bore stems
Eulophonotus myrmeleon Feldr.	Cocoa Stem Borer	Cossidae	E. & W. Africa	Larvae bore stems
Epigynopteryx coffeae Prout	Coffee Looper	Geometridae	Kenya	Larvae defoliate
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Africa	Larvae bore berries
Tortrix dinota Meyr.	Coffee Tortrix	Tortricidae	E. Africa	Larvae roll leaves
Archips occidentalis Wals.	Coffee Tortrix	Tortricidae	E. Africa	Larvae roll leaves
Homona coffearia Nietn.	Tea Tortrix	Tortricidae	Philippines	Larvae roll leaves
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia	Larvae damage fruits
Attacus atlas (L.)	Atlas Moth	Saturniidae	Philippines	Larvae defoliate
Cephonodes hylas L.	Coffee Hawk Moth	Sphingidae	Africa, India, S.E. Asia, Japan, Australasia	Larvae defoliate
Dasychira mendosa (Hb.)	Tussock Moth	Lymantriidae	Philippines	Larvae defoliate
Orgyia australis (Wlk.)	Tussock Moth	Lymantriidae	Philippines	Larvae defoliate
Prionoryctes caniculus Arr.	Yam Beetle	Scarabaeidae	Africa	Larvae damage roots
Pachnoda sinuata (F.)	Rose Beetle	Scarabaeidae	Kenya	Adults eat leaves

(continued)

Anomala spp.	White Grubs	Scarabaeidae	Philippines	Adults eat leaves; larvae in
Leucopholis spp.	White Grubs	Scarabaeidae	Philippines	soil eat roots
Aspidomorpha spp.	Tortoise Beetles	Chrysomelidae	Africa	Adults & larvae eat leaves
Ootheca mutabilis (Sahlb.)	Brown Leaf Beetle	Chrysomelidae	Africa	Adults & larvae eat leaves
Bixadus sierricola White	Coffee Stem Borer	Cerambycidae	Africa	Larvae bore stems
Xylotrechus quadripes Chevr.	Coffee Stem Borer	Cerambycidae	Philippines	Larvae bore stems
Aperitmetus brunneus (Hust.)	Tea Root Weevil	Curculionidae	Kenya	Larvae eat roots
Araeocerus fasciculatus (Deg.)	Coffee Bean Weevil	Brenthidae	Pantropical	Attack berries on tree and in store
Xylosandrus compactus (Eichh.)	Black Twig Borer	Scolytidae	Africa, India, S.E. Asia	Adults bore branches
Xylosandrus morigerus (Bland.)	Black Twig Borer	Scolytidae	S.E. Asia	Adults bore branches
Brevipalpus phoenicis (Geijskes)	Red Crevice Tea Mite	Tenuipalpidae	E. Africa, India, Mexico, Brazil	Scarify foliage
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Pantropical	Scarify foliage

COTTON (*Gossypium* spp. – Malvaceae)

Wild species are found in many parts of the tropics and subtropics. Commercial crops are grown now in the New World between 37° N and 32° S, and in the Old World between 47° N and 30° S. It cannot be grown successfully in India above 1000 m and in Africa above 2000 m; it needs 200 frost-free days, the optimum temperature for growth is 32° C, and the crop must have full sunshine (no shade); it can be grown on a variety of soils, but cannot tolerate very heavy rainfall; when grown 'rain-fed' the average rainfall needed is 100–150 cm, but in some areas it is grown under irrigation. The wild species are xerophytic. In habit they are annual sub-shrubs, 1–1.5 m high. The lint is used to make processed cotton; the seeds contain 18–24% edible oil, and the residual cake is rich in protein and used for cattle food. The main production areas are USA, China, USSR, Egypt, Mexico, Uganda, Nigeria, Tanzania, Sudan, India and the W. Indies. (See also Pearson, 1958, and Butani, 1975*a*.)

MAJOR PESTS

Aphis gossypii Glov.	Cotton Aphid	Aphididae	Cosmopolitan	Infest foliage
Empoasca fascialis Jacobi	Cotton Jassid	Cicadellidae	Africa	Infest foliage; virus vector
Empoasca lybica (De Berg)	Cotton Jassid	Cicadellidae	Africa, Spain, Israel	Infest foliage; virus vector
Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	Africa, India	Infest foliage; virus vector
Calidea dregii Germ.	Blue Bug	Pentatomidae	Africa	Sap-suckers; toxic saliva
Calidea bohemani (Stal)	Blue Bug	Pentatomidae	Africa	
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	Sap-sucker; toxic saliva
Oxycarenus hyalipennis Costa	Cotton Seed Bug	Lygaeidae	Africa, India, S.E. Asia, Brazil	Suck sap from seeds
Taylorilygus vosseleri (Popp.)	Cotton Lygus	Miridae	Africa	Cause leaf tattering
Helopeltis schoutedeni Reuter	Cotton Helopeltis	Miridae	Africa	Sap-sucker; toxic saliva
Dysdercus spp.	Cotton Stainers	Pyrrhocoridae	Africa, India	Sap-suckers; toxic saliva
Frankliniella schulzei (Trybom)	Cotton Flower Thrips	Thripidae	E. Africa, Sudan	Infest flowers
Sylepta derogata (F.)	Cotton Leaf Roller	Pyralidae	Africa, India, Australasia, China	Larvae roll leaves
Pectinophora gossypiella (Saund.)	Pink Bollworm	Gelechiidae	Pantropical	Larvae bore bolls
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Africa	Larvae bore bolls
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	Cosmopolitan in Old World	Larvae bore bolls
Helicoverpa zea Boddie	Cotton Bollworm	Noctuidae	USA	Larvae bore bolls
Earias biplaga Wlk.	Spiny Bollworm	Noctuidae	Africa	Larvae bore bolls
Earias insulana (Boisd.)	Spiny Bollworm	Noctuidae	Africa, India, S.E. Asia	Larvae bore bolls
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa, Near East	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India, S.E. Asia, Australasia	Larvae defoliate
Anomis flava (F.)	Cotton Semi-looper	Noctuidae	Africa, Asia, Australasia	Larvae eat leaves and buds
Diparopsis castanea Hmps.	Red Bollworm	Noctuidae	Southern Africa	Larvae bore bolls
Diparopsis watersi (Roths.)	Sudan Red Bollworm	Noctuidae	W. & N.E. Africa	Larvae bore bolls
Anthonomus grandis Boh.	Cotton Boll Weevil	Curculionidae	S. USA	Larvae in bolls
Pempheres affinis Faust.	Cotton Stem Weevil	Curculionidae	India, Thailand, Philippines	Larvae bore stems
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	Pantropical	Scarify leaves
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Cosmopolitan	Scarify leaves

MINOR PESTS

Zonocerus variegatus L.	Variegated Grasshopper	Acrididae	Africa	Defoliate
Austracris guttulosa Wlk.	Spur-throated Locust	Acrididae	Australia	Defoliate
Brachytrupes membranaceus (Drury)	Tobacco Cricket	Gryllidae	Africa	Destroy seedlings eat roots
Gryllus spp.	Field Crickets	Gryllidae	India	Destroy seedlings
Hodotermes mossambicus (Hagen)	Harvester Termite	Hodotermitidae	E. & S. Africa	Damage foliage
Microcerotermes parvus Haviland	–	Termitidae	E. Africa	Damage foliage

(continued)

Odontotermes obesus (Ram.)	Scavenging Termite	Termitidae	India	Damage foliage & seedlings
Empoasca devastans Dist.	Green Leafhopper	Cicadellidae	India, Thailand, Philippines	Sap-sucker; infests leaves
Amrasca spp.	Cotton Jassids	Cicadellidae	India, S.E. Asia	Sap-sucker; infests leaves
Paurocephala gossypii Russell	Cotton Psyllid	Psyllidae	Africa	
Planococcus citri (Risso)	Root Mealybug	Pseudococcidae	Pantropical	Infest roots & foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Philippines	Infest foliage
Ricania speculum (Wlk.)	Black Planthopper	Ricaniidae	Philippines	Infest foliage
Lygus oblineatus (Say)	Tarnished Plant Bug	Miridae	N. America	Sap-sucker; toxic saliva
Creontiades pallidus Ramb.	Cotton Mirid	Miridae	Africa, India	
Helopeltis spp.	Helopeltis Bugs	Miridae	Philippines	Sap-sucker; toxic saliva
Bagrada hilaris (Burm.)	Harlequin Bug	Pentatomidae	Africa, India	
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Scarify foliage
Hercinothrips femoralis Reut.	Banded Greenhouse Thrips	Thripidae	Cosmopolitan	Scarify foliage
Scirtothrips dorsalis Hood	Flower Thrips	Thripidae	India	Infest flowers
Ayyardia chaetophora Karny	Cotton Thrips	Thripidae	Thailand	Infest flowers
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	Philippines	Larvae bore stems
Acrocercops bifasciata Wlsm.	Cotton Leaf Miner	Gracillariidae	Africa	Larvae mine leaves
Parasa vivida (Wlk.)	Stinging Caterpillar	Limacodidae	E. & W. Africa	Larvae defoliate
Alabama argillacea (Hb.)	Alabama Leafworm	Noctuidae	N., C & S. America	Larvae defoliate
Trichoplusia ni (Hb.)	Cabbage Semi-looper	Noctuidae	USA, Mexico	Larvae defoliate
Chrysodeixis chalcites (Es.)	Cabbage Semi-looper	Noctuidae	Old World	Larvae defoliate
Spodoptera exigua (Hb.)	Lesser Armyworm	Noctuidae	Europe, Africa, India, Japan, USA	Larvae defoliate
Earias vittella Stoll	Spotted (Spiny) Bollworm	Noctuidae	India	Larvae bore bolls
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	Cosmopolitan	Larvae are cutworms
Sacadodes pyralis Dyar.	Sugarcane Stalk Borer/ South American Bollworm	Noctuidae	S. America	Larvae bore bolls
Tarache spp.	Cotton Semi-loopers	Noctuidae	India	Larvae defoliate
Xestia c-nigrum (L)	Spotted Cutworm	Noctuidae	Europe, Asia, N. America	Larvae are cutworms
Xanthodes graellsii (F.-A.)	Cotton Semi-looper	Noctuidae	Africa, Asia	
Hyles lineata (F.)	Silver-striped Hawk Moth	Sphingidae	Pantropical	Larvae defoliate
Bucculatrix thurberiella Busck	Cotton Leaf Perforator	Zygaenidae	USA, C. America	Larvae hole leaves
Diacrisia spp.	Tiger Moths	Arctiidae	Africa, India, S.E. Asia	Larvae defoliate
Estigmene acrea Drury	Salt Marsh Caterpillar	Arctiidae	USA	Larvae defoliate
Amsacta spp.	Tiger Moths	Arctiidae	India	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantriidae	E. Africa, India	Larvae defoliate
Contarinia gossypii Felt	Cotton Gall Midge	Cecidomyiidae	India, USA, W. Indies	Larvae infest buds
Dasyneura gossypii Felt	Cotton Flower Bud Midge	Cecidomyiidae	India	Larvae infest flower buds
Dacus spp.	Fruit Flies	Tephritidae	Africa, India, Australasia, Philippines	Larvae inside bolls
Podagrica spp.	Cotton Flea Beetles	Chrysomelidae	Africa, India	Adults hole leaves
Phyllotreta sp.	Flea Beetle	Chrysomelidae	Africa	Adults hole leaves
Ootheca mutabilis (Sahlb.)	Brown Leaf Beetle	Chrysomelidae	Africa	Adults eat leaves
Psallus seriatus (Reut.)	Cotton Fleahopper	Chrysomelidae	USA	Adults hole leaves
Apate spp.	Black Borers	Bostrychidae	Africa, Asia, C. & S. America	Adults bore stems
Coryna spp.	Pollen Beetles	Meloidae	Africa	Adults eat pollen
Mylabris spp.	Banded Blister Beetles	Meloidae	Africa, India, S.E. Asia	Adults eat flowers
Eriesthis vulpina Brum.	–	Scarabaeidae	Africa	Larvae in soil attack roots; adults eat leaves

(continued)

Pachnoda sinuata (F.)	Flower Beetle	Scarabaeidae	Africa	Larvae in soil attack roots; adults eat leaves
Epilachna spp.	Epilachna Beetles	Coccinellidae	Africa, Middle East	Adults & larvae eat leaves
Sphenoptera spp.	Cotton Jewel Beetle	Buprestidae	India, Africa	Larvae bore stems
Graphognathus spp.	White-fringed Weevils	Curculionidae	Africa, USA, S. America, Australia	Larvae eat roots, adults eat leaves
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	Thailand, China	Adults eat leaves
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Amorphoidea lata Mot.	Cotton Boll Weevil	Curculionidae	Philippines	Larvae in bolls
Amorphoidea sp.	Blossom Weevil	Curculionidae	Thailand	Adults eat flowers
Alcidodes gossypii (Hust.)	Striped Cotton Weevil	Curculionidae	Africa	Adult eats bark; girdling the stem
Apion soleatum Wagn.	Apion Weevil	Apionidae	E. Africa	Infest flowers
Aceria gossypii (Banks)	Cotton Gall Mite	Eriophyidae	India	Gall leaves
Eutetranychus orientalis (Klein)	Oriental Mite	Tetranychidae	Africa, India	Scarify foliage

Worldwide a total of 1,400 species of insect of mite pests are recorded.

COWPEA (*Vigna sinensis* – Leguminosae)

Despite its common name this plant is more closely related to beans than to peas. A vigorous bushy annual with cylindrical pendant pods. A crop of great antiquity, thought to be native to either C. Africa or C. America, but cultivated throughout S.E. Asia for more than 2000 years. Now widely grown throughout the tropics, mainly as a forage crop, cover crop, or as green manure; the seeds are fed to cattle and poultry. An important crop in India, China, and southern USA. It is susceptible to frost and heavy rainfall, and grown only in warm humid areas in light soils. The Oriental Longbean is *Vigna sesquipedalis* and is grown as a vegetable, and has a similar pest spectrum.

MAJOR PESTS				
Aphis craccivora (Koch)	Groundnut Aphid	Aphididae	Malaysia, Laos, India	Infest foliage
Lampides boeticus (L.)	Pea Blue Butterfly	Lycaenidae	Thailand, India	Larvae bore pods
Ophiomyia phaseoli (Coq.)	Bean Fly	Agromyzidae	Malaysia, India	Larvae mine stems
Callosobruchus chinensis (L.)	Oriental Cowpea Bruchid	Bruchidae	Thailand, Laos,	Attack ripe seeds in pods
MINOR PESTS				
Colemania sphenaroides Bol.	Deccan Wingless Grasshopper	Acrididae	India	Adults & nymphs defoliate
Empoasca spp.	Green Leafhoppers	Cicadellidae	India	Infest foliage & suck sap
Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	India	Infest foliage
Anchon pilosum W.	Treehopper	Membracidae	India	Infest stems
Creontiades pallidifer Wlk.	Capsid Bug	Miridae	India	Sap-sucker; toxic saliva
Chauliops fallax Scott	Cowpea Pod Bug	Lygaeidae	India	Sap-sucker; toxic saliva
Acanthocoris scabrator (F.)	Coreid Bug	Coreidae	Malaysia	Sap-sucker; toxic saliva
Anoplocnemis phasiana (F.)	Coreid Bug	Coreidae	India	Sap-sucker; toxic saliva
Riptortus spp.	Coreid Bugs	Coreidae	India	Sap-suckers; toxic saliva
Caliothrips indicus (Bagn.)	Thrips	Thripidae	India	Infest flowers
Taeniothrips spp.	Flower Thrips	Thripidae	India	Infest flowers
Acrocercops spp.	Leaf Miners	Gracillariidae	India	Larvae mine leaves
Cydia tricentra (Meyr.)	–	Tortricidae	India	Larvae eat foliage
Thosea aperiens (Wlk.)	Slug Caterpillar	Limacodidae	India	Larvae eat leaves
Etiella zinckenella (Triet.)	Pea Pod Borer	Pyralidae	India	Larvae bore pods
Maruca testulalis (Geyer)	Maruca Moth	Pyralidae	Malaysia, Laos, China	Larvae bore pods
Lamprosema spp.	Bean Leaf Rollers	Pyralidae	Malaysia, India	Larvae roll leaves
Nacoleia vulgaris Guen.	–	Pyralidae	India	Larvae eat foliage & pods
Amata passalis F.	Wasp-moth	Amatidae	India	Larvae eat leaves
Euchrysops cnejus	Blue Butterfly	Lycaenidae	India	Larvae bore pods
Amsacta spp.	Tiger Moths	Arctiidae	India	Larvae defoliate
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	India	Larvae are cutworms
Anticarsia irrorata B.	Green Leaf Caterpillar	Noctuidae	India	Larvae eats leaves
Helicoverpa armigera (Hbn.)	Old World Bollworm	Noctuidae	India	Larvae eat young shoots & bore pods
Spodoptera exigua (Hbn.)	Lesser Armyworm	Noctuidae	India	Larvae eat leaves
Spodoptera litura (F.)	Rice Armyworm	Noctuidae	India, Thailand	Larvae defoliate
Euproctis fraterna (Moore)	Tussock Moth	Lymantriidae	India	Larvae defoliate
Dasychira mendosa (Hbn.)	Tussock Moth	Lymantriidae	Malaysia	Larvae defoliate
Melanagromya obtusa M.	Bean Pod Fly	Agromyzidae	India	Larvae bore young seeds in pod
Anomala benghalensis Blanchard	Flower Beetle	Scarabaeidae	India }	Adults attack foliage; larvae eat roots in soil
Holotrichia spp.	Cockchafers	Scarabaeidae	India }	
Mylabris phalerata (Pall.)	Large Yellow-banded Blister Beetle	Meloidae	Laos	Adults eat leaves & flowers
Mylabris pustulata (Thunb.)	Banded Blister Beetle	Meloidae	India	Adults eat flowers

(continued)

Epilachna spp.	Epilachna Beetles	Coccinellidae	India	Adults & larvae eat leaves
Oulema spp.	Leaf Beetles	Chrysomelidae	India	Adults & larvae eat leaves
Phyllotreta sinuata (Steph.)	Flea Beetle	Chrysomelidae	Malaysia	Adults hole leaves
Callosobruchus maculatus (F.)	Spotted Cowpea Bruchid	Bruchidae	Thailand	Attack ripe seeds in open pods
Obera brevis S.	Stem Borer	Cerambycidae	India	Larvae bore stems

CUCURBITS (Marrow, Pumpkin, Melon, Watermelon, Squash, Cucumber, Loofah, etc – Cucurbitaceae)

Important cultivated species belong to nine separate genera within this family. Agriculturally the crops are really very diverse, but are biologically similar and have very similar pest spectra. Different species are native to different parts of the tropics (e.g. Watermelon to Africa; Marrow to the New World; Loofah in Asia). They are tendril-climbing or prostrate annuals with soft stems, table fruits, others as vegetables, some form gourds, and others loofahs. In temperate countries most cucurbits are cultivated under glass or polythene. (See also Butani & Varma, 1977.)

MAJOR PESTS				
Trialeurodes vaporarorium (Westw.)	Glasshouse Whitefly	Aleyrodidae	Europe	Infest foliage (greenhouse pest)
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	Africa, India, S.E. Asia, Australasia	Suck sap; toxic saliva
Dacus cucurbitae Coq.	Melon Fly	Tephritidae	E. Africa, India, S.E. Asia, Australasia	Larvae in fruits
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	S.E. Asia	Larvae in fruits
Dacus spp.	Fruit Flies	Tephritidae	S.E. Asia, India, Australasia	Larvae in fruits
Epilachna spp.	Epilachna Beetles	Coccinellidae	S.E. Asia	Adults & larvae eat leaves
Diabrotica undecimpunctata Mann.	Spotted Cucumber Beetle	Chrysomelidae	N. America	Adults defoliate; larvae eat roots
Raphidopalpa foveicollis (Lucas)	Red Pumpkin Beetle	Chrysomelidae	Med., India, Burma, Australia	Defoliate
Aulacophora spp.	Cucumber Beetles	Chrysomelidae	S.E. Asia, Africa	Adults defoliate
Tetranychus cinnabarinus (Boisd.)	Carmine Spider Mite	Tetranychidae	Cosmopolitan	Scarify leaves & web foliage (greenhouse pest)
Tetranychus spp.	Red Spider Mites	Tetranychidae	S.E. Asia	
Tetranychus urticae (Koch)	Temperate Red Spider Mite	Tetranychidae	Europe, Asia, N. America	
MINOR PESTS				
Onychiurus spp.	Springtails	Onychiuridae	Europe	Damage seedlings
Mecopoda elongata (L.)	Leaf Grasshopper	Tettigoniidae	Philippines	Eat leaves
Empoasca spp.	Green Leafhoppers	Cicadellidae	S.E. Asia	Infest leaves; sap-suckers; virus vectors
Bothrogonia ferruginea	Large Brown leafhopper	Cicadellidae	S.E. Asia	
Aphis gossypii Glov.	Melon/Cotton Aphid	Aphididae	Cosmopolitan	
Myzus persicae (Sulz.)	Peach–Potato Aphid	Aphididae	Cosmopolitan	
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	S.E. Asia	Infest foliage
Piezosternum calidum F.	Shield Bug	Pentatomidae	Africa	Sap-suckers; toxic saliva causes some fruit fall
Cyclopelta obscura (L. & S.)	Shield Bug	Pentatomidae	Philippines	
Coridius janus F.	Cucurbit Stink Bug	Pentatomidae	India	
Aspangopus spp.	Cucurbit Stink Bugs	Pentatomidae	India, Africa	
Anoplocnemis phasiana F.	Coreid Bug	Coreidae	Philippines	
Thrips tabaci Lind.	Onion Thrips	Thripidae	Europe	Infest foliage
Thrips fuscipennis Hal.	Rose Thrips	Thripidae	Europe	Infest foliage
Adoxophyes privatana (Wlk.)	Tortrix Moth	Tortricidae	Malaysia	Larvae roll leaves
Sphenarches caffer Zell.	Plume Moth	Pterophoridae	Africa, Asia, W. Indies	Larvae hole leaves
Palpita indica (Saund.)	Leaf-roller	Pyralidae	S. China	Larvae roll leaves
Helicoverpa armigera Hb.	Old World Bollworm	Noctuidae	Laos	Larvae bore fruit
Plusia spp.	Semi-loopers	Noctuidae	India, S.E. Asia	Larvae defoliate
Agrotis segetum (D. & S.)	Common Cutworm	Noctuidae	Philippines	Larvae are cutworm
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Philippines	Larvae are cutworm
Sciara spp.	Sciarid Flies	Sciaridae	Europe	Larvae damage roots (green house pest)

(continued)

Bactrocera cucurbitae	Fruit Fly	Tephritidae	SE Asia	Larvae bore fruit pedicel
Phytomyza horticola Gour.	Pea Leaf Miner	Agromyzidae	Cosmopolitan in Old World	Larvae mine leaves
Lasioptera falcata F.	Gall Midge	Cecidomyiidae	India	Larvae gall stems
Mylabris spp.	Banded Blister Beetles	Meloidae	Africa, India, S.E. Asia	Adults eat flowers
Ceratia frontalis	Leaf Beetle	Chrysomelidae	Thailand, Philippines	Adults defoliate
Copa kunowi Weise	Brown Flower Beetle	Chrysomelidae	Africa	Adults eat flowers
Epilachna chrysomelina	Epilachna Beetle	Chrysomelidae	Africa	Adults & larve eat leaves
Raphidopalpa similis	Leaf Beetle	Chrysomelidae	Thailand	Adults defoliate
Phyllotreta crucifera (Goeze)	Cabbage Flea Beetle	Chrysomelidae	Africa, India	Adults hole leaves
Monolepta bifasciata (Hornst.)	Leaf Beetle	Chrysomelidae	Malaysia	Adults defoliate
Diabrotica spp.	Cucumber Beetles	Chrysomelidae	S. USA	Adults & larvae damage plants
Anomala spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Apomecyna spp.	Vine Borers	Cerambycidae	Philippines, India	Larvae bore vines
Tyrophagus dimidiatus	Mushroom Mite	Tyroglyphidae	Europe	Damage foliage (greenhouse pest)
Eutetranychus orientalis (Klein)	Oriental Mite	Tetranychidae	Africa, India	Scarify foliage

CUSTARD APPLE (*Annona squamosa* – Annonaceae) (= Sugar Apple; Sweetsop)

A native to the W. Indies and S. America, but now grown widely throughout the tropics for its edible fruit. The fruit is large (7–10 cm diameter), heart-shaped, green in colour, covered with rounded fleshy tubercles which represent the loosely joined carpels. The pulp is granular, white, sweet, and rather like custard. It is used mainly as a dessert fruit. The plant is a woody shrub, seldom grown commercially but commonly in gardens or near houses. The ripe fruits are soft and perishable and difficult to transport, and are mostly consumed locally.

Annona muricata is the Soursop of C. America; *A. reticulata* is Bullock's Heart; and *A. montana* is the Mountain Soursop. (See also Butani, 1976*b*.)

MAJOR PESTS				
Planococcus spp.	Mealybugs	Pseudococcidae	S.E. Asia, India	Infest fruits
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India, Ethiopia	Infest fruits
Anonaepestis bengalella (Rag.)	Fruit Borer	Pyralidae	India	Larvae bore fruit
MINOR PESTS				
Dinleuropora decempunctata (Q. & B.)	Whitefly	Aleyrodidae	India	Infest foliage
Ceroplastes floridensis Comst.	Soft Scale	Coccidae	India	Encrust foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	India	Encrust foliage
Coccus spp.	Soft Scales	Coccidae	Ethiopia	
Laccifer communis Mahd.	Lac Insect	Lacciferidae	India	Encrust twigs
Retithrips syriacus (Mayet)	Castor Thrips	Thripidae	India	Infest leaves
Rhipiphorothrips cruentatus Hood	Grapevine Thrips	Thripidae	India	Infest leaves
Pyroderces falcetalla St.	–	Cosmopterygidae	India	Larvae bore stems
Dacus persicae B.	Peach Fruit Fly	Tephritidae	India	Larvae inside fruit
Dacus zonatus (Saund.)	Peach Fruit Fly	Tephritidae	India	Larvae inside fruits
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Totricidae	Ethiopia	Larvae inside fruit
Coccotrypes carpophagus Horn	Seed Scolytid	Scolytidae	India	Adults bore seeds

DATE PALM (*Phoenix dactyliferae* – Palmae)

One of the earliest crop plants, having been cultivated for at least 5000 years; probably native to Arabia or India, but now naturalized throughout S.W. Asia and N. Africa. In habit a typical tall palm bearing clusters of fruit at the crown; the texture of the fruit varies with the variety. The Date Palm can grow in more arid areas than any other crop and hence is of great value in desert areas. The fruit has a high food value, with a sugar content of some 54% and 7% protein. Most of the commercial dates come from Iraq, the rest from N. Africa, Arabia, California and Arizona. Propagation is either by seed or by cuttings. (See also Butani, 1975*d*, and Carpenter & Elmer, 1978.)

MAJOR PESTS				
Parlatoria blanchardii (Targ.)	Date Palm Scale	Diaspididae	Africa, Asia Minor, India, Australia, S. America	Infest foliage & fruits
Ephestia cautella (Hb.)	Almond (Fig) Moth	Pyralidae	Pantropical	Larvae eat fruits
Oryctes rhinoceros (Oliv.)	Rhinoceros Beetle	Scarabaeidae	India	Adults damage crown
Oligonychus spp.	Date Mites	Tetranychidae	N. Africa, Iraq, Iran, S. USA	Scar leaves & fruits
MINOR PESTS				
Odontotermes obesus (Rambur)	Scavenging Termite	Termitidae	India	Damage trunk
Ommatissus binotatus Fieb.	Dubas Bug	Tropiduchidae	N. Africa, Iran, Iraq, Egypt	Infest foliage
Pseudococcus spp.	Mealybugs	Pseudococcidae	Pantropical	Infest foliage
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	Pantropical	Infest foliage
Aonidiella orientalis (Newst.)	Oriental Yellow Scale	Diaspididae	Pantropical	Infest foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	India	Infest foliage & fruits
Ischnaspis longirostris (Sign.)	Black Line Scale	Diaspididae	Pantropical	Infest foliage
Phoenicoccus marlatti (Ckll.)	Red Date Scale	Ericoccidae	Pantropical	Infest leaf bases
Asterolecanium phoenicis (Rao)	Green Date Scale	Asterolecaniidae	Egypt, Israel, Iran, Iraq	Infest foliage & fruits
Arenipses sabelia (Hmpsn.)	Greater Date Moth	Pyralidae	N. Africa, Egypt, Iran, Iraq, India	Larvae damage fruits
Paramyelois transitella (Wlk.)	Navel Orangeworm	Pyralidae	USA (California)	Larvae damage fruits
Batrachedra amydraula (Meyr.)	Lesser Date Moth	Cosmopterygidae	Iran, Iraq, Yemen, Egypt, Arabia, India	Larvae damage fruits
Nephantis serinopa Meyr.	Black-headed Caterpillar	Xyloryctidae	India	Larvae defoliate
Parasa spp.	Stinging Caterpillars	Limacodidae	China	Larvae defoliate
Oecophylla smaragdina F.	Red Tree Ant	Formicidae	India	Nest in crown; attack workers
Vespa spp.	Common Wasps	Vespidae	Pantropical	Adults pierce fruit
Carpophilus spp.	Fig Beetle (etc.)	Nitidulidae	Pantropical	Damage ripening fruits
Oryctes spp.	Rhinoceros Beetles	Scarabaeidae	Africa, Iraq, India, Iran	Adults damage crown
Suastus gremius F.	Skipper	Hesperiidae	India	Larvae eat leaves
Chalcophora japonica Gory	Jewel Beetle	Buprestidae	China }	Larvae bore trunk
Chrysobothris succedanea Saund.	Flat-headed Borer	Buprestidae	China }	
Pseudophilus testaceus Gah.	Palm Stem Borer	Cerambycidae	Egypt, Iran, Iraq, Arabia	Larvae bore trunk & petioles
Rhynchophorus phoenicis (F.)	African Palm Weevil	Curculionidae	Africa	Larvae bore crown & trunk
Rhynchophorus ferrugineus Oliv.	Asiatic Palm Weevil	Curculionidae	Iraq, India, Indonesia,	Larvae bore crown & trunk
Diocalandra spp.	Coconut Weevils	Curculionidae	Africa, Asia, Australasia	Larvae bore tissues
Coccotrypes dactyliperda (F.)	Date Stone Beetle	Scolytidae	N. Africa, Egypt, Israel, India, S. USA	Adults bore fruits
Brevipalpus phoenicis (Geijskes)	Red Crevice Tea Mite	Tenuipalpidae	Pantropical	Scarify foliage
Raoiella indica Hirst	Date Palm Scarlet Mite	Tenuipalpidae	Sudan, Egypt, India	Scarify foliage

DECCAN HEMP (*Hibiscus cannabinus* – Malvaceae) (= Kenaf, etc.)

This tall annual herb yields a fibre known by many different common names, and has long been used in the Old World tropics as a substitute for jute and hemp in the manufacturing of coarse canvas, cordage, matting, fishing nets, etc. The fibres are 2–3 m in length and are usually extracted from the stems of the plants by retting. The seeds contain 20% oil, which has certain commercial uses. It is a common wild plant in tropical Africa, which is probably its original home, but is now being grown widely throughout the tropics and sub-tropics as a fibre crop.

MAJOR PESTS				
Maconellicoccus hirsutus (Green)	Hibiscus Mealybug	Pseudococcidae	India	Infest foliage; stunt or kill shoots
MINOR PESTS				
Amrasca biguttula Ish.	Leafhopper	Cicadellidae	India	Inhibit leaves
Pinnaspis strachani (Cooly)	Armoured Scale	Diaspididae	India	Encrust stems
Dysdercus cingulatus (Fb.)	Cotton Stainer	Pyrrhocoridae	India	Sap-sucker; toxic saliva
Nezara viridula L.	Green Stink Bug	Pentatomidae	India	Sap-sucker; toxic saliva
Pectinophora gossypiella (Saund.)	Pink Bollworm	Gelechiidae	India	Larvae bore fruits
Earias insulana Boisd.	Spiny Bollworm	Noctuidae	India	Larvae bore fruits
Earias vittella (F.)	Spotted Bollworm	Noctuidae	India	Larvae bore fruits
Anomis flava F.	Cotton Semi-looper	Noctuidae	India	Larvae defoliate
Porthesia scintillans Wlk.	Tussock Moth	Lymantriidae	India	Larvae defoliate
Agrilus acutus Thnb.	Jute Stem Borer	Buprestidae	India	Larvae bore stems
Mylabris pustulata Th.	Banded Blister Beetle	Meloidae	India	Adults deflower
Podagrica spp.	Cotton Flea Beetles	Chrysomelidae	India	Adults hole leaves
Alcidodes affaber F.	Stem Weevil	Curculionidae	India	Adult girdles stem
Dereodus mastos Hb.	Leaf Weevil	Curculionidae	India	Adults eat leaves

EGGPLANT (*Solanum melongena* – Solanaceae) (= Brinjal; fruit called Aubergine)

Found wild and first cultivated in India; now cultivated throughout the tropics. It grows well up to 1000 m in altitude on light soils. It is a perennial, weakly erect herb, 0.5–1.5 m in height; with a fruit that is a large pendant berry, ovoid or oblong and 5–15 cm long, smooth in texture and usually black or purple when ripe. The fruit is eaten as a vegetable, boiled, fried, or stuffed. Propagation is by seed. It is grown throughout the tropics for local consumption but some countries (e.g. Kenya) are developing an export trade with Europe. (See also Butani & Varma, 1976*a*.)

MAJOR PESTS

Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	India	Infest foliage
Phthorimaea operculella (Zeller)	Potato Tuber Moth	Gelechiidae	Cosmopolitan	Larvae bore stem
Euzophera perticella (Rag.)	Brinjal Stem Borer	Pyralidae	India	Larvae bore stem
Leucinodes orbonalis Guen.	Eggplant Boring Caterpillar	Pyralidae	Thailand, Laos, Malaysia, India	Larvae bore stem
Epicauta spp.	Black Blister Beetles	Meloidae	Asia, USA, Africa	Adults eat flowers
Epilachna spp.	Epilachna Beetles	Coccinellidae	India, S.E. Asia	Adults & larvae eat leaves

MINOR PESTS

Oxya japonica (Thnb.)	Small Rice Grasshopper	Acrididae	India	Adults & nymphs eat leaves
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Cosmopolitan	Infest leaves & stems; virus vectors
Macrosiphum euphorbiae (Thos.)	Potato Aphid	Aphididae	Cosmopolitan	
Myzus persicae (Sulz.)	Green Peach Aphid	Aphididae	S.E. Asia, India	
Amrasca spp.	Leafhoppers	Cicadellidae	India, S.E. Asia	Infest foliage
Empoasca spp.	Green Leafhoppers	Cicadellidae	S.E. Asia, India, Africa	Infest leaves & stems
Quadraspidiotus destructor Sign.	San José Scale	Diaspididae	India	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	S.E. Asia, India	Infest stems & leaves
Orthezia insignis Browne	Jacaranda Bug	Orthezidae	India, Malaysia, Africa, N., C. & S. America	Infest stems & leaves
Terentius nubifasciastus	Treehopper	Membracidae	Papua NG	Sap-suckers
Tricentrus bicolor Dist.	Treehopper	Membracidae	India	Sap-suckers
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Africa, Asia	Toxic saliva; sap-suckers
Creontiades pallidifer Wlk.	Capsid Bug	Miridae	India	Toxic saliva; sap-suckers
Cyrtopeltis tenuis (Reut.)	Tobacco Capsid	Miridae	Pantropical	
Dysdercus spp.	Cotton Stainers	Pyrrhocoridae	S.E. Asia	Toxic saliva; sap-suckers
Corythaica passiflaorae Berg.	Lace Bug	Tingidae	West Indies	
Urentius spp.	Brinjal Lace Bugs	Tingidae	India	Toxic saliva; sap-suckers
Gargaphia solani Heid.	Eggplant Lace Bug	Tingidae	USA	
Thrips tabaci Lind.	Onion Thrips	Thripidae	India	Infest foliage
Thrips palmi	Palm Thrips	Thripidae	S.E. Asia, China	
Scrobipalpa heliopa (Lower)	Tobacco Stem Borer	Gelechiidae	India, S.E. Asia, Africa	Larvae bore stems
Eublemma olivacea (Wlk.)	Brinjal Leaf Roller	Tortricidae	India	Larvae roll leaves
Homona coffearia (Guen.)	Tea Tortrix	Tortricidae	Papua NG	Larvae roll leaves
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	S.E. Asia, India	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Helicoverpa assulta Gn.	Cape Gooseberry Budworm	Noctuidae	India, S.E. Asia, Africa, Australasia	Larvae bore buds
Agrotis ipsilon (Hufn.)	Black Cutworm	Noctuidae	India	Larvae are cutworms
Plusia orichalcea F.	–	Noctuidae	India	Larvae eat leaves
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	S.E. Asia	Larvae bore buds & fruit
Antoba olivacea (Wlk.)	–	Noctuidae	India	Larvae defoliate
Phytometra chalcites (Esp.)	Semi-looper	Noctuidae	Malaysia	Larvae defoliate
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	S.E. Asia	Larvae defoliate

(continued)

Acherontia spp.	Deaths Head Hawk Moths	Sphingidae	Laos, India	Larvae defoliate
Oulema spp.	Leaf Beetles	Chrysomelidae	India, Africa	Adults & larvae eat leaves
Rhyparida coriacea	Leaf Beetle	Chrysomelidae	Papua NG	Adults eat leaves
Leptinotarsa decemlineata (Say)	Colorado Beetle	Chrysomelidae	Europe, N. & C. America	Adults & larvae defoliate
Epitrix spp.	Flea Beetles	Chrysomelidae	West Indies	
Psylliodes spp.	Flea Beetles	Chrysomelidae	Philippines	Adults eat leaves, make holes
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Anomala spp	White Grubs	Scarabaeidae	Philippines, India	Larvae eat roots
Holotrichia consanguinea Blanch.	Cockchafer	Scarabaeidae	India	Larvae eat roots
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Trichobaris trinotata (Say)	Potato Stalk Borer	Curculionidae	USA	Larvae bore stalks
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	S.E. Asia	Scarify foliage
Tetranychus cinnabarinus (Boisd.)	Carmine Spider Mite	Tetranychidae	S.E. Asia, India	Scarify foliage
Tetranychus spp.	Red Spider Mites	Tetranychidae	Cosmopolitan	Scarify leaves & web foliage

FIG (*Ficus carica* – Moraceae)

A native of Asia Minor and spread early into the Mediterranean Region; of great antiquity as a crop, being grown in Egypt before 4000 BC. The fruit may be eaten fresh, stewed, dried or now canned. The tree is of moderate size, up to 10 m in height with large palmate leaves. The main producing areas are around the Mediterranean (Turkey, Greece, Italy) and California, with some production in Australia. The plant does not flourish in the low wet tropics, but can be grown at higher elevations and drier parts of the tropics. The widely cultivated Smyrna fig variety requires pollination by the symbiotic wasp *Blastophaga psenes* for fruit development, but the common or Adriatic variety develops parthenocarpically. Wild species of *Ficus* are widespread and common throughout the tropics and several banyan species are grown as shade and avenue trees. (See also Butani, 1975*b*.)

MAJOR PESTS				
Ceratitis capitata (Wied.)	Medfly	Tephritidae	Europe, Africa, Australia, C. & S. America	Larvae inside fruits
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	Cosmopolitan	Infest leaves
Ephestia cautella (Hb.)	Almond Moth	Pyralidae	S.E. Asia	Attack ripe & stored fruits
Batocera spp.	Longhorn Beetles	Cerambycidae	Med., E. Africa, India, Malaysia, China, Japan	Larvae bore trunk & branches
MINOR PESTS				
Velu caricae Ghauri	Fig Leafhopper	Cicadellidae	India	Infest leaves
Cosmocarta niteara Dist.	Spittlebug	Cercopidae	India	Sap-suckers
Planococcus citri (Risso)	Root Mealybug	Pseudococcidae	Cosmopolitan	On roots & foliage
Planococcus spp.	Mealybugs	Pseudococcidae	India	Infest foliage
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	Cosmopolitan	Infest foliage
Mesohomotoma ficus (L.)	Fig Psyllid	Psyllidae	S. Europe, W. Asia	Infest foliage
Pauropsylla depressa Crawf.	Fig Leaf Psyllid	Psyllidae	India	Nymphs gall leaves
Lepidosaphes conchiformis (L.)	Mussel Scale	Diaspididae	Europe, Africa, Asia, Japan, USA, S. America	Infest foliage
Kerria fici (Green)	Fig Lac Insect	Lacciferidae	India	Infest twigs
Coccus hesperidium L.	Soft Brown Scale	Coccidae	Cosmopolitan	Infest foliage
Ceroplastes sinensis Del G.	Chinese Waxy Scale	Coccidae	Almost cosmopolitan	Infest foliage
Ceroplastes rubens Mask.	Pink Waxy Scale	Coccidae	E. Africa, Asia	Infest foliage
Ceroplastes rusci (L.)	–	Coccidae	Med.	Infest foliage
Saissetia oleae Bern.	Black Scale	Coccidae	Cosmopolitan	Infest foliage
Drosicha mangiferae (Green)	Mango Giant Mealybug	Margarodidae	India	Infest foliage
Icerya purchasi Mask.	Cottony Cushion Scale	Margarodidae	Cosmopolitan	Infest foliage
Aspidiotus destructor (Sign.)	Coconut Scale	Diaspididae	India	Infest foliage
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Infest foliage
Frankliniella spp.	Flower Thrips	Thripidae	Cosmopolitan	Infest foliage
Gigantothrips elegans Zimm.	Giant Fig Thrips	Phlaeothripidae	India	Infest leaves
Udumbaria nainiensis Grover	Fig Midge	Cecidomyiidae	India	Larvae inside fruits
Anjeerodiplosis peshawarensis Mani	Fig Midge	Cecidomyiidae	India	Larvae inside fruits
Dacus zonatus Saund.	Peach Fruit Fly	Tephritidae	India	Larvae inside fruits
Dacus orientalis (Hend.)	Oriental Fruit Fly	Tephritidae	India	Larvae inside fruits
Lonchaea aristella Beck.	Fig Fly	Lonchaeidae	Med.	Larvae inside fruits
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	S.E. Asia	Larvae bore branches
Zeuzera pyrina L.	Leopard Moth	Cossidae	Med.	Larvae bore branches
Azochis gripusalis Wlk.	–	Pyralidae	Brazil, Mexico	Larvae eat foliage
Diaphania spp.	–	Pyralidae	India	Larvae defoliate
Paramyelois transitella (Wlk.)	Navel Orange-worm	Pyralidae	USA (California)	Larvae bore fruits
Parasa lepida (Cram.)	Blue-striped Nettlegrub	Limacodidae	India	Larvae eat leaves
Simaethis nemorona	–	Glyphipterygidae	Med. & Australia	Larvae eat foliage

(continued)

Phycodes spp.	–	Glyphipterygidae	India	Larvae web leaves
Spodoptera litura F.	Rice Cutworm	Noctuidae	India	Larvae defoliate
Heliothis spp.	–	Noctuidae	India	Larvae bore fruits
Ocinara variana Wlk.	Tussock Moth	Lymantriidae	India	Larvae defoliate
Perina nuda F.	Banyan Tussock Moth	Lymantriidae	India	Larvae defoliate
Carpophilus hemipterus (L.)	Dried Fruit Beetle	Nitidulidae	Cosmopolitan	Feed on dried figs
Adoretus spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves
Cotinis spp.	–	Scarabaeidae	S. USA	Adults defoliate
Apriona spp.	Longhorn Beetles	Cerambycidae	India, S. China	Larvae bore branches
Hesperophanes spp.	Longhorn Beetles	Cerambycidae	Med., S.E. Asia	Larvae bore branches
Olenecamptus spp.	Longhorn Beetles	Cerambycidae	India, China	Larvae bore branches
Omophoras stomachosus	Fig weevil	Curculionidae	S. Africa	Larvae bore twigs
Hypoborus ficus Erichs.	Fig Twig Borer	Scolytidae	Med.	Adults bore twigs
Eutetranychus orientalis (Klein)	Oriental Mite	Tetranychidae	Africa, India	Scarify foliage
Aceria ficus (Cottee)	Fig Leaf Mite	Eriophyidae	India	Scarify foliage
Eriophyes ficivorus Ch. Bas.	Fig Gall Mite	Eriophyidae	India	Distort leaves

GINGER (*Zingiber officinale* – Zingiberaceae)

Native to S.E. Asia this plant is an erect perennial herb (1 m tall) with a thick scaly rhizome that branches digitately. The yellowish flowers are borne in a spike. Most cultivation is in small home gardens, in a moist tropical climate; the plant is propagated by the rhizomes. The rhizomes are pale yellow externally and yellowish green inside, and contain starch, oleoresin, gums and essential oils. Ginger is prepared either as preserved or green ginger, or dried (cured) ginger. It is widely used as a condiment (rather than a spice), in culinary preparation, beverages, and medicine. Grown chiefly in China, Japan, Sierra Leone, Indonesia, Queensland, Australia, and the W. Indies.

MAJOR PESTS

MINOR PESTS

Pentalonia nigronervosa Coq.	Banana Aphid	Aphididae	Pantropical	Infest leaf-bases
Aspidiella hartii (Ckll.)	Yam Scale	Diaspididae	India, W. Africa, W. Indies	Encrust rhizome
Acrocercops irridians Meyr.	Leaf Miner	Gracillariidae	India	Larvae mine leaves
Dichocrocis punctiferalis Guen.	Shoot Borer (Castor Capsule Borer)	Pyralidae	Malaysia, India, China	Larvae bore shoots
Udaspes folus (Cr.)	Grass Demon (Turmeric Skipper)	Hesperiidae	S. China, India, Malaysia	Larvae roll leaves
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Malaysia	Larvae defoliate
Chalcidomyia atricornis Mall.	Shoot Fly	Chloropidae	India, Bangladesh	Larvae bore shoots & rhizome
Formosina flavipes Mall.	Shoot Fly	Chloropidae	India, Bangladesh	Larvae bore shoots & rhizome
Calobata sp.	Rhizome Fly	Micropezidae	India	Larvae bore rhizome
Mimegralla coerubifrons Mall.	Rhizome Fly	Micropezidae	Bangladesh	Larvae bore rhizome
Celyphus sp.	Rhizome Fly	Celyphidae	India	Larvae bore rhizome
Hedychorus rufofasciatus M.	Leaf Weevil	Curculionidae	India	Adults nibble leaves

GRAPEVINE (*Vitus vinifera* – Vitaceae)

V. vinifera is the European or Wine Grape; there are several native American species with larger and more hardy fruit, and these are more resistant to diseases and pests. The European grapevine is one of the oldest cultivated plants, and probably originated in the Caspian Sea area of western Asia. They were spread all over Europe with the Roman civilization, and are now found in all warm temperate regions and in higher areas in many tropical countries. It is a woody, climbing, tendril-bearing vine, with large palmate leaves, small and insignificant flowers leading to large clusters of fruit. The fruit is technically a berry, and is either eaten fresh, dried as raisins, or currants, or the juice is pressed out to make wine. Raisins are dried wine grapes of high quality, and may be seedless like the Sultana variety. Currants are small dried grapes from a variety that grows in Greece. The chief grape-growing areas are Europe, USA, Argentina, Chile, Australia and S. Africa. Propagation is by stem cuttings. (See also Butani, 1974*b*.) Subtropical/warm temperate regions.

MAJOR PESTS				
Erythroneura spp.	Grape Leaf-hoppers	Cicadellidae	Canada, USA	Infest foliage; sap-suckers
Viteus vitifolii (Fitch)	Grape Phylloxera	Phylloxeridae	Europe, USA	Leaves galled
Planococcus spp.	Root Mealybugs	Pseudococcidae	Cosmopolitan	Infest rootstocks
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Widespread	Infest stems
MINOR PESTS				
Odontotermes obesus (Ramb.)	Scavenging Termite	Termitidae	India	Damage roots
Aleurocanthus spiniferus Quaint	Orange Spiny Whitefly	Aleyrodidae	S. & E. Asia	Infest foliage
Aleurocanthus woglumi (Ashby)	Citrus Blackfly	Aleyrodidae	India	Infest foliage
Maconellicoccus hirsutus (Green)	Hibiscus Mealybugs	Pseudococcidae	India	Kill shoots
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	Infest foliage
Lecanium spp.	Soft Scales	Coccidae	India	Encrust foliage
Saissetia oleae (Colv.)	Black Scale	Coccidae	India	Encrust foliage
Parasaissetia nigra (Niet.)	Nigra Scale	Coccidae	India	Encrust foliage
Parthenolecanium corni (Bouche)	Plum Scale	Coccidae	Europe	Encrust foliage
Kerria lacca (Kerr.)	Lac Insect	Lacciferidae	India	Encrust stems
Aspidiotus spp.	Hard Scales	Diaspididae	India	Encrust foliage
Aphis gossypii (Glov.)	Cotton Aphid	Aphididae	India	Infest foliage
Retithrips syriacus (Mayet)	Black Vine Thrips	Thripidae	Med., India, Africa	Infest leaves
Rhipiphorothrips cruentatus Hood	Thrips	Thripidae	India	Infest leaves
Scirtothrips dorsalis Hood	Thrips	Thripidae	India	Infest foliage
Lobesia botrana (Schiff.)	Grape Berry Moth	Tortricidae	Europe, Japan, E. Africa	Larvae destroy fruit
Paralobesia viteana (Clem.)	Grape Berry Moth	Tortricidae	N. America	Larvae destroy fruit
Cnephasia longana (Haw.)	Omnivorous Leaf Roller	Tortricidae	Switzerland, S. USA	Larvae roll leaves
Epiphyas postvittana (Wlk.)	Light Brown Apple Moth	Tortricidae	Australia, NZ	Larvae eat leaves
Acherontia spp.	Death's Head Hawk Moth	Sphingidae	India	
Hippotion celerio	Vine Hawk Moth (Silver Striped Hawk)	Sphingidae	Africa, Asia	Larvae defoliate
Hyles lineata (F.)	Striped Hawk Moth	Sphingidae	Pantropical	Larvae defoliate
Thereta spp. (4)	Hawk Moths	Sphingidae	India	
Sylepta lunalis (Guen.)	Grape Leaf Roller	Pyralidae	India	Larvae roll leaves
Paramyelois transitella (Wlk.)	Navel Orange-worm	Pyralidae	USA	Larvae damage fruits
Clysia ambiguella (Hb.)	Vine Moth	Phalaonidae	Europe, China, Japan	Larvae bore stems
Othreis fullonia L.	Fruit-piercing Moth	Noctuidae	India	Adults pierce fruits
Achaea janata L.	Fruit-piercing Moth	Noctuidae	India	Adults pierce fruits
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India	Larvae eat leaves

(continued)

Xestia c-nigrum (L.)	Spotted Cutworm	Noctuidae	Europe, Asia, N. America	Larvae eat leaves
Euproctis spp.	Tussock Moths	Lymantriidae	India	Larvae eat leaves
Dacus cucurbitae (Coq.)	Melon Fly	Tephritidae	India	Maggots bore fruits
Vespa spp.	Common Wasps	Vespidae	Cosmopolitan	Adults puncture berries
Polistes olivaceous (F.)	Paper Wasp	Vespidae	India	Adults puncture berries
Colaspis brunnea (F.)	Grape Colaspis	Chrysomelidae	S. USA	Adults eat leaves
Scelodonta strigicollis (Mot.)	Flea Beetle	Chrysomelidae	India	Adults eat shoots; larvae eat roots
Nodostoma spp.	Leaf Beetles	Chrysomelidae	India	Defoliate
Oides decempunctata (Billb.)	Ten-spotted Leaf Beetle	Chrysomelidae	S. China, India	Adults & larvae eat leaves
Monolepta spp.	Spotted Leaf Beetles	Chrysomelidae	India	Adults hole leaves
Adoretus spp.	Cockchafers	Scarabaeidae	India	Adults defoliate
Anomala spp.	Flower Beetles	Scarabaeidae	India, Africa	Adults eat leaves
Brahmina coriacea (Hope)	Cockchafer	Scarabaeidae	India	Adults defoliate
Holotrichia longipennis (Blanch.)	Cockchafer	Scarabaeidae	India	Adults eat leaves; larvae eat roots
Sthenia (*grisator* F.) spp.	Girdler Beetles	Cerambycidae	India, Africa	Larvae girdle stems
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Xyleborus semiopacus Eich.	Black Twig Borer	Scolytidae	India	Adults bore stems
Tetranychus urticae (Koch)	Temperate Red Spider Mite	Tetranychidae	Europe	Scarify foliage
Eutetranychus orientalis (Klein)	Oriental Mite	Tetranychidae	India	Scarify foliage
Oligonychus spp.	Grape Spider Mites	Tetranychidae	India, Africa	Scarify foliage
Brevipalpus californicus (Banks)	–	Tenuipalpidae	Cosmopolitan	Scarify foliage
Eriophyes vitis (Pgst.)	Grape Gall Mite	Eriophyidae	USA	Erinea on leaves
Calepitrimerus vitis (Can.)	Grape Rust Mite	Eriophyidae	USA	Scarify foliage

In some areas starlings are serious pests of ripening grapes

GRASS (Many species – Gramineae)

It is not feasible to consider the different species and genera of grasses separately because of the number involved. Certain pest species are restricted to certain species of grass, but in general most of the pests listed are polyphagous and attack a wide range of host species, this being especially the case for the soil-dwelling larvae. Many of the pests listed under the various graminaceous crops (e.g. cereals and sugar-cane) are to be found infesting species of grasses, and frequently grasses are the natural wild hosts from which the pests spread on to the cereal crops.

MAJOR PESTS

Locusta migratoria sspp.	Migratory Locusts	Acrididae	Africa, Asia	Defoliate
Many species	Short-horned Grasshoppers	Acrididae	Cosmopolitan	Defoliate
Gryllotalpa spp.	Mole Crickets	Gryllotalpidae	Cosmopolitan	Destroy roots
Gryllus spp.	Field Crickets	Gryllidae	Cosmopolitan	Defoliate & destroy roots
Hodotermes mossambicus (Hagen)	Harvester Termite	Hodotermitidae	E. & S. Africa	Defoliate
Odontotermes badius (Hartland)	Crater Termite	Termitidae	Tropical Africa	Defoliate
Nephotettix spp.	Green Leafhoppers	Cicadellidae	Africa, Asia	Sap-suckers; virus vectors
Many species	Leafhoppers	Cicadellidae	Cosmopolitan	
Many species	Planthoppers	Delphacidae	Cosmopolitan	Sap-suckers; virus vectors
Hysteroneura setariae (Th.)	Rusty Plum Aphid	Aphididae	Pantropical & USA	
Rhopalosiphum spp.	Grass Aphids	Aphididae	Holarctic	Sap-suckers
Schizaphis graminum (Rond.)	Wheat Aphid	Aphididae	Cosmopolitan	Sap-sucker
Macrosiphum spp.	Grass Aphids	Aphididae	Cosmopolitan	Sap-suckers
Metopolophium spp.	Grass Aphids	Aphididae	Cosmopolitan	Sap-suckers
Saissetia oleae (Ol.)	Black Scale	Coccidae	Sub-tropical	Infest foliage
Antonia graminis (Mask.)	Rhodes Grass Scale	Diaspididae	Pantropical	Encrust foliage
Brevennia rehi (Ldgr.)	Rice Mealybug	Pseudococcidae	India, S.E. Asia, S. USA	Infest foliage
Antinothrips spp.	Grass Thrips	Thripidae	Europe	Infest flowers
Ostrinia spp.	Corn Borers	Pyralidae	Cosmopolitan	Larvae bore stems
Several species	Grass Stem Borers	Pyralidae	Cosmopolitan	Larvae bore stems
Diatraea saccharalis (F.)	Sugarcane Borer	Pyralidae	S. USA, C. & S. America	Larvae bore stems
Crambus spp.	Grass Moths	(Crambidae)	Cosmopolitan	Larvae defoliate
Hepialus spp.	Swift Moths	Hepialidae	Palaearctic	Larvae in soil eat roots
Several species	Skippers	Hesperiidae	Cosmopolitan	Larvae roll leaves
Spodoptera frugiperda (J.E.S.)	Fall Armyworm	Noctuidae	N., C. & S. America	Larvae defoliate
Spodoptera exempta (Wlk.)	African Armyworm	Noctuidae	Africa, India, S.E. Asia, Australia	Larvae defoliate
Spodoptera spp.	Armyworms, etc.	Noctuidae	Pantropical	Larvae defoliate
Remigia repanda (F.)	Guinea Grass Moth	Noctuidae	C. & S. America	Larvae defoliate
Opomyza spp.	Grass Flies	Opomyzidae	Palaearctic	Larvae bore shoots
Geomyza spp.	Grass Flies	Opomyzidae	Palaearctic	Larvae bore shoots
Oscinella spp.	‘Frit’ Flies	Chloropidae	Palaearctic	Larvae gall stems
Chlorops spp.	Gout Flies	Chloropidae	Palaearctic	Larvae gall stems
Tipula spp. etc.	Leatherjackets	Tipulidae	Palaearctic	Larvae in soil eat roots
Mayetiola spp.	‘Flax’ Midges	Cecidomyiidae	Europe	Larvae distort stems
Contarinia spp.	Grass Flower Midges	Cecidomyiidae	Europe	Larvae in flower head
Amaurosoma spp.	Grass Midges	Cordyluridae	Europe	Larvae gall spike
Atherigona spp.	Shoot Flies	Muscidae	Cosmopolitan	Larvae destroy shoot
Several species	Shoot Flies	Anthomyiidae	Cosmopolitan	Larvae destroy shoot
Messor barbarus L.	Harvester Ant	Formicidae	E. Africa	Defoliate

Atta spp. / *Acromyrmex* spp.	Leaf-cutting Ants	Formicidae	W. Indies, C. & S. America	Defoliate
Agriotes spp. etc.	Wireworms	Elateridae	Palaearctic	Larvae in soil eat roots
Lacon spp. etc.	Tropical Wire-worms	Elateridae	Pantropical	Larvae in soil eat roots
Oulema spp.	Cereal Leaf Beetles	Chrysomelidae	Cosmopolitan	Larvae mine leaves adults eat strips
Anomala spp.	White Grubs	Scarabaeidae	Cosmopolitan	Larvae live in soil and feed on plant roots; especially serious to Gramineae & pastures.
Adoretus spp.	White Grubs	Scarabaeidae	Pantropical	Adults may damage plant foliage
Cetonia spp.	White Grubs	Scarabaeidae	Cosmopolitan	Larvar in soil eat roots, adults eat leaves.
Heterony chus spp.	Cereal Beetles	Scarabaeidae	Pantropical	Larvar in soil eat roots, adults eat leaves.
Holotrichia spp.	White Grubs	Scarabaeidae	Pantropical	Larvar in soil eat roots, adults eat leaves.
Melolontha spp.	Chafer Grubs	Scarabaeidae	Cosmopolitan	Larvar in soil eat roots, adults eat leaves.
Leucopholis spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvar in soil eat roots, adults eat leaves.
Schizonycha spp.	White Grubs	Scarabaeidae	Africa	Larvar in soil eat roots, adults eat leaves.
Protaetia spp.	White Grubs	Scarabaeidae	Pantropical	Larvar in soil eat roots, adults eat leaves.
Phyllobius spp.	Common Leaf Weevils	Curculionidae	Palaearctic	Larvae in soil eat grass roots
Many species	Weevils	Curculionidae	Cosmopolitan	Larvae in soil eat grass roots

GROUNDNUT (*Arachis hypogaea* – Leguminosae)

This crop originated in the Grand Chaco area of S. America, and has been cultivated in Mexico and the W. Indies since pre-Columbian times. The 16th century Spaniards introduced it to W. Africa, Philippines, China, Japan, Malaya, India and Madagascar. Now it is grown in all tropical and sub-tropical countries, up to 40°N and S of the equator. It is a warm season crop and is killed by frost; mostly grown in areas of 100 cm or more rainfall: it needs 50 cm rain during the growing season, and dry weather for ripening. It is a small erect or trailing herb, 15–60 cm high. Seeds are produced underground in pods; the seeds are rich in oil (38–50%), protein, and vitamins B and C. The main production areas are India, China, Nigeria, Sudan, Senegal, Niger, Gambia, USA, Brazil and Argentina. (See also Feakin, 1973.)

MAJOR PESTS				
Aphis craccivora Koch	Groundnut Aphid	Aphididae	Pantropical	Infest foliage; virus vector
Hilda patruelis Stål	Groundnut Hopper	Tettigometridae	Africa	Subterranean sap-suckers
Taeniothrips sjostedti (Trybom)	Bean Flower Thrips	Thripidae	Africa	Infest flowers
Frankliniella schulzei (Trybom)	Cotton Flower Thrips	Thripidae	E. Africa, Sudan	Infest flowers
Etiella zinckenella (Triet.)	Pea Pod Borer	Pyralidae	Malaysia	Larvae bore pods
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Spodoptera exigua Hub.	Lesser Armyworm	Noctuidae	Europe, Africa, India, Japan, USA	Larvae defoliate
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	Old World tropics	Larvae damage pods & foliage
Schizonycha spp.	Chafer Grubs	Scarabaeidae	Africa	Larvae eat roots
Diabrotica undecimpunctata Mann.	Spotted Cucumber Beetle	Chrysomelidae	USA	Adults defoliate, larvae in soil eat pods.
Ootheca mutabilis (Salhb.)	Brown Leaf Beetle	Chrysomelidae	E. Africa, Nigeria	Defoliate
Epicauta albovittata (Gestro)	Striped Blister Beetle	Meloidae	E. Africa, Somalia	Adults eat flowers
Epicauta spp.	Black Blister Beetles	Meloidae	Asia, USA, Africa	Adults eat flowers
Alcidodes dentipes (Ol.)	Striped Sweet Potato Weevil	Curculionidae	Africa	Adult girdles stem; larvae gall stem
Systates spp.	Systates Weevils	Curculionidae	Africa	Adults eat leaves
Graphognathus spp.	White-fringed Weevils	Curculionidae	S. Africa, Australia, NZ, USA, S. America	Adults eat leaves; larvae eat roots
MINOR PESTS				
Locusta migratoria sspp.	Migratory Locusts	Acrididae	Africa, Asia	Defoliate
Odontotermes spp.	Scavenging Termites	Termitidae	Africa, India	Damage roots foliage
Hodotermes mossambicus (Hag.)	Harvester Termite	Hodotermitidae	S. & E. Africa	Defoliate
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Africa, India	Infest foliage
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	Pantropical	Infest foliage
Pseudococcus spp.	Mealybugs	Pseudococcidae	Africa, Australia, C. & S. America	Infest foliage
Empoasca spp.	Green Leafhoppers	Cicadellidae	Africa, India, USA, S. America	Infest foliage
Cicadulina spp.	Maize Leafhoppers	Cicadellidae	Africa	Infest foliage
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	Sap-sucker; toxic saliva
Bagrada spp.	Harlequin Bugs	Pentatomidae	Africa, Asia	Sap-suckers, toxic saliva
Anoplocnemis phasiana (F.)	Coreid Bug	Coreidae	Indo-China	Sap-sucker; toxic saliva
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	Africa, Asia, Australasia	Sap-sucker; toxic saliva
Euborellia stali Dohrn.	Earwig	Forficulidae	S. India	Damage pods
Frankliniella fusca Hinds.	Tobacco Thrips	Thripidae	USA	Infest flowers
Caliothrips indicus (Bagn.)	–	Thripidae	Africa, India	Infest foliage

(continued)

Parasa vivida (Wlk.)	Stinging Caterpillar	Limacodidae	E. & W. Africa	Larvae defoliate
Parasa lepida (Cram.)	Blue-striped Nettlegrub	Limacodidae	India, S.E. Asia	Larvae defoliate
Stegasta basqueella (Chambers)	Red-necked Peanutworm	Gelechiidae	USA, Brazil	Larvae bore buds
Stegasta variana (Meyr.)	Peanutworm	Gelechiidae	Malaysia	Larvae bore buds
Stomopteryx subsecivella Zell.	Groundnut Leaf Miner	Gracillariidae	India, S.E. Asia	Larvae mine leaves
Homona coffearia (Nietn.)	Tea Tortrix	Tortricidae	Papua NG	Larvae roll leaves
Archips micaceana (Wlk.)	Tortrix	Tortricidae	Indo-China	Larvae roll leaves
Maruca testulalis (Geyer)	Mung Moth	Pyralidae	Cosmopolitan	Larvae bore pods
Elasmopalpus lignosellus (Zell.)	Lesser Cornstalk Borer	Pyralidae	S. USA, S. America	
Lampides boeticus (L.)	Pea Blue	Lycaenidae	Indo-China	Larvae bore pods
Diacrisia obliqua Wlk.	Tiger Moth	Arctiidae	India	Larvae defoliate
Amsacta moorei (Wlk.)	Tiger Moth	Arctiidae	India, Australasia	Larvae defoliate
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	Cosmopolitan	Larvae are cutworms
Spodoptera frugiperda (J.E. Smith)	Black Armyworm	Noctuidae	USA, C. & S. America	Larvae are cutworms
Spodoptera litura (F.)	Rice Armyworm	Noctuidae	India, S.E. Asia	Larvae defoliate
Achaea finita Gn.	Semi-looper	Noctuidae	Africa	Larvae defoliate
Dorylus orientalis Westw.	Oriental Army Ant	Formicidae	Indo-China	Defoliation
Gonocephalum spp.	Dusty Brown Beetles	Tenebrionidae	Africa	Adults damage plant
Diabrotica spp.	Leaf Beetles (Rootworms)	Chrysomelidae	USA, S. America	Adults defoliate; larvae eat pods.
Schizonycha spp.	Chafer Grubs	Scarabaeidae	Africa	Larvae eat roots
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae eat roots
Leucopholis spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots
Eulepida mashona Arr.	White Grub	Scarabaeidae	Africa	Larvae eat roots
Strigoderma arboricola F.	White Grub	Scarabaeidae	S. USA	Larvae eat roots
Rhopaea magmicornis Blkb.	Pasture White Grub	Scarabaeidae	Australia	Larvae eat roots
Mylabris spp.	Banded Blister Beetles	Meloidae	Pantropical	Adults eat flowers
Caryedon serratus (Oliv.)	Groundnut Bruchid	Bruchidae	W. Africa	Infest pods in field & stores
Sphenoptera perotetti Guer.	Jewel Beetle	Buprestidae	India	Larvae bore stems
Zygrita diva Thoms.	Lucerne Crown Borer	Cerambycidae	Australia	Larvae bore stems
Tetranychus spp.	Red Spider Mites	Tetranychidae	Cosmopolitan	Scarify foliage

GUAVA (*Psidium guajava* — Myrtaceae)

Guava is indigenous to tropical America, but is now pantropical in distribution, mostly grown for local consumption, but areas of large production and export are India, Florida, Brazil and Guyana. It is grown throughout the tropics from sea-level to 2000 m in a wide range of soils and climate. A hardy, shallow-rooted shrub, or small tree, 3–10 m in height. The fruit is a large berry with seeds embedded in the edible pulp which is white or red in colour. The fruit is eaten raw or cooked, and is rich in vitamins C and A; can be used for jam, jelly, paste or juice, and also dried as a vitamin source. Fruits are produced when the tree is eight years old. (See also Butani, 1974*c*.)

MAJOR PESTS				
Coccus alpinus De Lotto	Soft Green Scale	Coccidae	E. Africa	Infest foliage
Chloropulvinaria psidii Mask.	Guava Scale	Coccidae	Pantropical	Infest foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Cosmop.	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Icerya purchasi Mask.	Cottony Cushion Scale	Margarodidae	Cosmopolitan	Infest foliage
Selenothrips rubrocinctus (Giard)	Red-banded Thrips	Thripidae	Pantropical	Infest leaves
Dacus dorsalis (Hend.)	Oriental Fruit Fly	Tephritidae }	Malaysia, Laos, Philippines, India, Hawaii }	
Ceratitis capitata spp.	Medfly	Tephritidae		Larvae in fruit
Anastrepha spp.	Guava Fruit Flies	Tephritidae	W. Indies	
MINOR PESTS				
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	China	Infest foliage
Aphis gossypii (Glover)	Cotton Aphid	Aphididae	Malaysia, Laos, Philippines, India	Infest foliage
Planococcus lilacinus (Ckll.)	–	Pseudococcidae	S.E. Asia, India, Madagascar	Infest foliage
Nipaecoccus nipae (Mask.)	Nipa Mealybug	Pseudococcidae	India, Africa, C. America	Infest foliage
Parthenolecanium persicae (F.)	Peach Scale	Coccidae	Cosmopolitan	Infest foliage
Coccus viridis (Green)	Soft Green Scale	Coccidae	Pantropical	Infest foliage
Coccus hesperidum L.	Soft Brown Scale	Coccidae	Cosmopolitan	Infest foliage
Icerya aegyptica (Dgl.)	Egyptian Fluted Scale	Margarodidae	India, Africa, S.E. Asia, Australia	Infest foliage
Drosicha mangiferae Green	Mango (Giant) Mealybug	Margarodidae	India	Infest foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Infest foliage
Chrysomphalum aonidum (L.)	Florida Red Scale	Diaspididae	Philippines	Infest foliage
Aonidiella orientalis Newst.	Oriental Yellow Scale	Diaspididae	India (Pantropical)	Infest foliage
Hemiberlesia lataniae (Sign.)	Latania Scale	Diaspididae	Cosmopolitan in warm areas	Infest foliage
Helopeltis schoutedeni Reuter	Cotton Helopeltis	Miridae	Africa	Sap-sucker; toxic saliva
Helopeltis theobromae (Miller)	Cocoa Helopeltis	Miridae	Malaysia	Toxic saliva
Pseudotheraptus wayi Brown	Coconut Bug	Coreidae	E. Africa	Toxic saliva
Attacus atlas (L.)	Atlas Moth	Saturniidae	Philippines	Larvae defoliate
Microclona leucosticta (Meyr.)	Guava Stem Borer	Gelechiidae	India	Larvae bore shoots
Eripnyis ello (L.)	Hawk Moth	Sphingidae	USA	Larvae defoliate
Virachola isocrates F.	Blue Butterfly	Lycaenidae	India	Larvae feed inside fruits
Indarbela tetraonis Moore	Wood-borer Moth	Metarbelidae	India, China	Larvae eat bark
Othreis fullonia (Clerke)	Fruit-piercing Moth	Noctuidae	Philippines, India }	Larvae defoliate; adults pierce fruit
Achaea spp.	Fruit-piercing Moths	Noctuidae	Africa, India	
Thosea sinensis (Wlk.)	Slug Caterpillar	Limacodidae	Philippines	Larvae defoliate
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Africa }	Larvae bore fruits
Argyresthia eugeniella Busch.	–	Tortricidae	?	
Metanestria hyrtaca (Cram.)	–	Lasiocampidae	Philippines	Larvae defoliate

(continued)

Trabala irrorata (Moore)	–	Lasiocampidae	Malaysia	Larvae defoliate
Dichocrocis punctiferalis (Guen.)	Castor Capsule Borer	Pyralidae	India	Larvae bore shoots
Dacus zonatus Saund.	Peach Fruit Fly	Tephritidae	India, China	Larvae bore fruit
Dacus diversus (Coq.)	Guava Fruit Fly	Tephritidae	India	Larvae inside fruit
Dacus cucurbitae Coq.	Melon Fly	Tephritidae	India, China	Larvae inside fruit
Anastrepha fraterculus (Wied.)	Guava Fruit Fly	Tephritidae	C. & S. America	Larvae inside fruit
Anastrepha mombinpraeoptans Sein	West Indian Fruit Fly	Tephritidae	C. & S. America	Larvae inside fruit
Adoretus spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves
Aeolesthes holosericea F.	Cherry Stem Borer	Curculionidae	India, S.E. Asia	Larvae bore stem
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	Laos	Adults eat leaves
Stephanoderes psidii Hoph.	Guava Bark Borer	Scolytidae	Philippines	Adults bore bark
Brevipalpus phoenicis (Geijskes)	Red Crevice Tea Mite	Tenuipalpidae	India	Damage fruits
Tenuipalpus puniicae	–	Tenuipalpidae	India	Damage fruits

HEMP (*Cannabis sativa* — Cannabinaceae) (= Indian Hemp)

The term 'hemp' is confusing as it is applied loosely to include a number of quite unrelated plants and commercial fibres. But this is the true hemp; native to C. and W. Asia, but now widely cultivated in both tropical and temperature regions. The plant is a stout, bushy annual 2–4 m tall, dioecious, with hollow stem and palmate leaves. The fibre is a white bast which develops in the pericycle of the stem; it is long, strong, and durable, but being lignified is not very flexible. The fibre is used mainly for ropes, sacks, sailcloth and twine. The seeds contain an oil that can be used as a substitute for linseed oil. The dried flowering tops of the female plants are pressed into a solid mass and used as narcotic stimulant. The active principle is a resin containing three or four very powerful alkaloids; the extracted resin is usually called hashish, whereas the dried leaves are known as marijuana or bhang. The cultivation of hemp is usually subject to close supervision, if permitted at all, because of it being a source of a popular narcotic.

MAJOR PESTS				
Empoasca spp.	Green Leaf-hoppers	Cicadellidae	Thailand	Infest leaves
Cydia delineata Wlk.	Hemp Leaf-roller	Tortricidae	Yugoslavia	Larvae bore leaves stems & fruits
Cydia sinana	Hemp Moth	Tortricidae	Japan, Pakistan, Thailand	Larvae eat leaves & bore petioles
MINOR PESTS				
Ostrinia nubilalis (Hb.)	European Corn Borer	Pyralidae	Europe, N. America	Larvae bore stem
Phytomyza horticola Gout.	Pea Leaf Miner	Agromyzidae	Japan, etc.	Larvae mine leaves
Liriomyza cannabis Hend.	Hemp Leaf Miner	Agromyzidae	Japan	
Phalonia epilinana L.		Cochylidae	China	Caterpillars eat leaves
Mordellistena cannabisi Mats.	Hemp Flea Beetle	Chrysomelidae	China	Adults eat leaves
Psylliodes attenuata Kock	Hemp Flea Beetle	Chrysomelidae	China	
Paraglenea fortunei Saunders	Longhorn Beetle	Cerambycidae	China	Larvae bore stem
Thyestilla gebleri Feld.	Longhom Beetle	Cerambycidae	China	
Podagrica sp.	Cotton Flea Beetle	Chrysomelidae	Thailand	Adults hole leaves
Ceutorhynchus rubripes Hust.	Hemp Weevil	Curculionidae	Japan	
Hypomeces squamosus F.	Gold-dust Weevil	Curculionidae	Thailand	Adults eat leaves

HYACINTH BEAN (*Lablab niger* – Leguminosae) (= *Dolichos lablab)* (= Indian Bean; Bovanist Bean)

This is an herbaceous perennial herb, often grown as an annual, 1–6 m in height, either twining or as a bush; the young pods and tender beans are popular vegetables in India and elsewhere in the tropics. The dried seeds are used as a split pulse, for human food, and also for livestock feed. The haulms are used as livestock fodder. Sometimes the crop is grown as green manure or as a cover crop. It is grown as a dryland crop, being hardy and drought-resistant, and can be grown in areas with as little as 60–90 cm of rainfall. The species is widely grown throughout Asia.

MAJOR PESTS				
Coptosoma cribraria F.	Stink Bug	Pentatomidae	India	Sap-sucker; toxic saliva
Adisura atkinsoni Moore	Pod Borer	Noctuidae	India	Larvae bore pods
MINOR PESTS				
Bemisia tabaci (Genn.)	Cotton Whitefly	Aleyrodidae	India	Infest foliage
Trialeurodes rara Singh	Castor Whitefly	Aleyrodidae	India	Infest foliage
Aphis craccivora Koch	Groundnut Aphid	Aphididae	India	Infest foliage
Ceroplastes cajani Mask.	Soft Scale	Coccidae	India	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	Infest foliage
Haplothrips vernoniae Pr.	Flower Thrips	Phlaeothripidae	India	Infest flowers
Frankiniella sulphurea Schm.	Flower Thrips	Thripidae	India	Infest flowers
Ayyaria chaetophora Ky.	Leaf Thrips	Thripidae	India	Infest leaves
Cosmopteryx phaeogastra Meyr.	Leaf Miner	Cosmopterygidae	India	Larvae mine leaves
Thosea aperiens Wlk.	Stinging Caterpillar	Limacodidae	India	Larvae defoliate
Laspeyresia torodelta Meyr.	Pod Borer	Tortricidae	India	Larvae bore pods
Etiella zinckenella Treit.	Pea Pod Borer	Pyralidae	India	Larvae bore pods
Lamprosema indicata F.	Webworm	Pyralidae	India	Larvae web leaves
Diacrisia obliqua Wlk.	Tiger Moth	Arctiidae	India	Larvae defoliate
Acherontia spp.	Death's Head Hawk Moths	Sphingidae	India	Larvae defoliate
Anticarsa irrorata F.	Green Leaf Caterpillar	Noctuidae	India	Larvae defoliate
Helicoverpa armigera Hb.	American Bollworm	Noctuidae	India	Larvae bore pods
Ophiomyia phaseoli (Coq.)	Bean Fly	Agromyzidae	India	Larvae bore stem
Sagra nigrita Oliv.	Stem Borer	Chrysomelidae	India	Larvae bore stems
Alcidodes spp.	Stem Weevils	Curculionidae	India	Adults girdle stems

JACKFRUIT (*Artocarpus heterophyllus* – Moraceae)

An Indo-Malaysian species, now widely dispersed in the tropics. It is a handsome evergreen tree 10–20 m tall, with entire leaves, and huge fruits up to 0.5 m long and weighing 10–20 kg, which are borne on the trunk and main branches (cauliflory). Although widely grown throughout the tropics, it is not used much except in Asia, especially southern India. (See also Butani, 1978*a*.)

MAJOR PESTS				
Diaphania caesalis (Wlk.)	Jackfruit Shoot Borer	Pyralidae	India, Malaysia, Philippines	Larvae bore shoots
Dacus umbrosus (F.)	Fruit Fly	Tephritidae	S.E. Asia	Larvae in fruit
Ochyromera artocarpi Mshl.	Jackfruit Bud Weevil	Curculionidae	India	Larvae bore buds
MINOR PESTS				
Greenidea artocarpi (Wests.)	Jackfruit Aphid	Aphididae	India	Infest twigs
Cosmocarta relata Dist.	Spittlebug	Cercopidae	India	Feed on twigs
Pealius schimae Tak.	Blackfly	Aleyrodidae	India	Infest leaves
Icerya seychellarum (Westw.)	Seychelles Fluted Scale	Margarodidae	Philippines, India	Infest twigs
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	Infest twigs
Pseudococcus spp.	Mealybugs	Pseudococcidae	Philippines	Infest foliage
Ceroplastes rubens Mask.	Pink Waxy Scale	Coccidae	India	Infest foliage
Chloropulvinaria psidii (Mask.)	Guava Scale	Coccidae	India	Infest foliage
Aonidiella aurantii (Mask.)	Red Scale	Diaspididae	Philippines	Infest leaves
Hemiberlesia lantaniae (Sign.)	Armoured Scale	Diaspididae	India	Infest foliage
Oecophylla smaragdina (F.)	Red Tree Ant	Formicidae	India	Attack workers
Dacus dorsalis (Hend.)	Oriental Fruit Fly	Tephritidae	India	Larvae in fruits
Indarbela tetraonis (Moore)	Wood-borer Moth	Metarbelidae	India	Larvae bore bark & wood
Diaphania bivitralis (Gn.)	Jackfruit Leaf-webber	Pyralidae	India	Larvae web leaves
Thosea sinensis Wlk.	Slug Caterpillar	Limacodidae	Laos	Larvae defoliate
Perina nuda F.	Banyan Tussock Moth	Lymantriidae	India	Larvae defoliate
Apriona germari	Jackfruit Longhorn	Cerambycidae		
Apriona spp.	Jackfruit Longhorns	Cerambycidae	S.E. Asia	Larvae bore in trunk
Batocera spp.	Longhorns	Cerambycidae	S.E. Asia	& branches
Sthenias grisator F.	Longhorn	Cerambycidae	India	
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	Malaysia	Adults eat leves

JUJUBE (*Zizyphus mauritiana* – Rhamnaceae) (= *Z. jujuba* (L.) Lam. *non* Mill.) (= Indian Jujube; Ber)

A small thorny evergreen tree, widespread throughout Africa and Asia in dried regions, and widely cultivated in India for the small edible fruit. The fruit is brown in colour, oval and about 2–3 cm in length, with edible acid pulp and a hard central stone. It is eaten fresh or dried and used as dessert, but is also candied and makes a very refreshing drink. The fruit is also a rich source of vitamin C.

Zizyphus jujuba Mill. is the Chinese Jujube, a tree of temperate climates and has been cultivated in China for at least 4000 years. (See also Butani, 1973.)

MAJOR PESTS				
Drosichiella tamarandus Green	Ber Mealybug	Margarodidae	India	Infest foliage
Corpomyia vasuviana Costa	Ber Fruit Fly	Tephritidae	India	Larvae inside fruits
Adoretus spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves; larvae eat roots
Yonthochelus superciliosis Gyll.	Ber Weevil	Curculionidae	India	Adults defoliate; larvae in soil eat roots
Myllocerus spp.	Leaf Weevils	Curculionidae	India	Adults eat leaves
MINOR PESTS				
Drosicha mangiferae Green	Mango Giant Mealybug	Margarodidae	India	Infest foliage
Nipaecoccus spp.	Mealybugs	Pseudococcidae	India	Infest foliage
Aonidiella spp.	Armoured Scales	Diaspididae	India	Encrust twigs
Aonidia ziziphi Rah.	Ber Scale	Diaspididae	India	Encrust twigs
Pulvinaria spp.	Soft Scales	Coccidae	India	Infest foliage
Urentius ziziphifolius M. & H.	Ber Lacebug	Tingidae	India	Sap-sucker; toxic saliva
Indarbela spp.	Wood-boring Moths	Metarbelidae	India	Larvae eat bark & bore branches
Virachola isocrates F.	Anar Butterfly	Lycaenidae	India	Larvae bore fruits
Porthmologa parclina Meyr.	Leaf-eating Caterpillar	Pyralidae	India	Larvae eat leaves
Thiacides postica Wlk.	Hairy Caterpillar	Noctuidae	India	Larvae defoliate
Dasychira spp.	Tussock Moths	Lymantriidae	India	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantriidae	India	Larvae defoliate
Dacus spp.	Fruit Flies	Tephritidae	India	Larvae inside fruits
Platypria andrewesi Weise	Hispid Beetle	Chrysomelidae	India	Larvae mine leaves; adults eat strips
Neocollyris bonelli G-M	Tiger Beetle	Carabidae	India	Larvae in twigs
Holotrichia insularis Br.	Cockchafer	Scarabaeidae	India	Adults eat leaves
Tanymecus spp.	Leaf-eating Weevils	Curculionidae	India	Adults eat leaves

JUTE (*Corchorus* spp. – Tiliaceae)

Probably the most widely used fibre in the world (other than cotton); it is a bast fibre from the secondary phloem of two species of *Corchorus*. The plant is a tall, slender, half-shrubby annual, some 2–3 m in height, of Asiatic origin, and is now almost entirely an Indian crop, although some is grown in Brazil. (See also Dean, 1979.)

MAJOR PESTS				
Dasychira mendosa Hon.	Jute Hairy Caterpillar	Lymantriidae	India	Larvae defoliate
Spilosoma obliqua (Wlk.)	Jute Hairy Caterpillar	Lymantriidae	India	Larvae defoliate
MINOR PESTS				
Brachytrupes portentosus (Licht.)	Large Brown Cricket	Gryllidae	Bangladesh	Cut seedlings
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	Encrust foliage
Pectinophora gossypiella (Saund.)	Pink Bollworm	Gelechiidae	India	Larvae bore flowers
Anomis sabulifera (Gn.)	Jute Semi-looper	Noctuidae	India, Africa, S.E. Asia, Australasia	Larvae defoliate
Achaea spp.	Fruit-piercing Moths	Noctuidae	India	Larvae defoliate
Spodoptera exigua (Hb.)	Beet Armyworm	Noctuidae	India	Larvae defoliate
Agrilus acutus Thnb.	Jute Stem Borer	Buprestidae	India	Larvae bore stem
Apion corchori Marsh	Jute Stem Weevil	Apionidae	Bangladesh	Larvae bore stem
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	India	Infest foliage

KAPOK (*Ciba pentandra* – Bombacaceae)

A lowland tropical tree, up to 30 m tall, probably originating in tropical American forests, now well established as different varieties in W. Africa and Asia. Kapok is the floss from the inner capsule wall of the fruit in which the seeds lie loosely when ripe. Each hair is a single cell, 1–3 cm long, waxy, elastic, light and water-repellant, and with a buoyancy five times that of cork. Because of these properties it is used for stuffing and insulating purposes. It is light (eight times lighter than cotton), has low thermal conductivity, and is a very effective sound absorber. Exporting countries include Thailand, Indonesia, E. Africa, India and Pakistan.

MAJOR PESTS				
Crypticerya jacobsoni (Green)	–	Margarodidae	Laos	Infest shoots & pods
Mudaria variabilis Roepke	Pod Moth	Noctuidae	Laos, Indonesia	Larvae bore pods
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Plocaederus obesus Gahan	Longhorn	Cerambycidae	Thailand, Laos	Larvae bore trunk
Alcidodes leeweni (Hall.)	Twig Borer	Curculionidae	Indonesia	Larvae bore twigs & shoots
MINOR PESTS				
Odontotermes sp.	Scavenging Termite	Termitidae	Thailand	Workers damage trunk and roots
Globitermes suphureus Haviland	Termite	Termitidae	Thailand	
Aphis gossypii (Glov.)	Cotton Aphid	Aphididae	Philippines	Infest leaves
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Philippines	Encrust foliage
Planococcoides njalensis (Laing)	Cocoa Mealybug	Pseudococcidae	W. & C. Africa	Infest foliage
Saissetia nigra (Nietm.)	Nigra Scale	Coccidae	Philippines	Infest leaves
Distaniella theobroma (Dist.)	Cocoa Capsid	Miridae	W. Africa	Sap-sucker; toxic saliva
Tectocoris diopthalmus Thunb.	Red Shield Bug	Pentatomidae	Philippines	
Odontophus nigricornis Stal.	Leaf-sucking Bug	Pyrrhocoridae	Thailand	
Dysdercus spp.	Cotton Stainers	Pyrrhocoridae	S.E. Asia	
Lygaeus hospes F.	–	Lygaeidae	Solomon Isl.	
Zeuzera coffeae (Nietn.)	Red Coffee Borer	Cossidae	Philippines	Larvae bore branches
Cheromettia lohor	Gelatine Caterpiller	Limacodidae	SE Asia	Larvae defoliate
Cryptothelea spp.	Bagworms	Psychidae	Philippines	Larvae defoliate
Mudaria spp.	Kapok Borers	Noctuidae	India, Indonesia	Larvae bore pods
Dasychira mendosa (Hub.)	Tussock Moth	Lymantrudae	Philippines	Larvae defoliate
Anomala spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots
Heterobostrychus acqualis (Waterh.)	Kapok Borer	Bostrychidae	Philippines	Adults bore branches
Batocera sp.	Longhorn Beetle	Cerambycidae	Philippines, Mauritius	Larvae bore trunk
Alcidodes obesus Faust	Stem-boring Weevil	Curculionidae	Thailand, Laos, Malaysia	Larvae bore twigs
Desmidophorus spp.	Weevils	Curculionidae	Thailand, Laos	Adults eat leaves
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	Laos, Malaysia	Adults eat leaves

KOLA (*Cola* spp. – Sterculiaceae) (= Kola-nut)

About 60 species grow naturally in tropical Africa, mostly W. Africa; a small to medium evergreen tree, leaves simple and entire. The seeds, in slightly fleshy pods borne in leaf axils, are chewed as a stimulating narcotic, and in addition to being used as a masticatory, the powdered seeds may be boiled in water and used as a beverage. Mostly planted in W. Africa where it is an important crop; four species are generally cultivated.

MAJOR PESTS				
Toxoptera aurantii B. de F.	Black Citrus Aphid	Aphididae	Pantropical	Infest foliage
Parasaissetia nigra (Nietn.)	Nigra Scale	Coccidae	Old World	Infest foliage
Selenothrips rubrocinctus Giard.	Red-banded Thrips	Thripidae	Pantropical	Infest foliage
Helopeltis bergrothis Reut.	Cocoa Mosquito Bug	Miridae	Tropical Africa	Sap-sucker; toxic saliva
Sahlbergella singularis Hagl.	Cocoa Capsid	Miridae	Africa	Sap-sucker; toxic saliva
Balanogastris kolae (Desbr.)	Kola Weevil	Curculionidae	W. Africa	Larvae bore nuts
Paremydica inseperata Faust	Weevil	Curculionidae	W. Africa	Larvae bore nuts
MINOR PESTS				
Brachytrupes membranaceus Drury	Tobacco Cricket	Gryllidae	Africa	Seedling attacked
Zonocerus variegatus L.	Stink Grasshopper	Acrididae	Africa	Defoliate
Planococcoides njalensis (Laing)	Cocoa Mealybug	Pseudococcidae	Africa	Infest foliage
Sylepta retractalis Hmps.	Leaf-roller	Pyralidae	W. Africa	Larvae roll leaves
Anaphe venata Btlr.	Tent Caterpillar	Notodontidae	W. Africa, Zaïre	Gregarious larvae defoliate
Characoma stictigrapha Hmps.	Pod Husk Borer	Noctuidae	W. Africa	Larvae eat leaves & pods
Ceratitis colae Silv.	Kola Fruit Fly	Tephritidae	W. Africa	Larvae bore pods
Apate monachus F.	Black Borer	Bostrychidae	Africa	Adults bore branches
Phosphorus gabonator Thoms.	Longhorn Beetle	Cerambycidae	W. Africa, Zaïre	Larvae bore trunk
Zyrcosa brunnea Hust.	Leaf Weevil	Curculionidae	W. Africa	Adults eat leaves

LENTIL (*Lens esculenta* – Leguminosae)

One of the most ancient of food plants and also one of the most nutritious. Its origin was S.W. Asia. The plant is a slender, much-branched annual with short broad pods. The seeds are used mostly in soups, and are more easily digested than meat. The plants are sometimes used as fodder for animals. The main production areas are India, Pakistan, Ethiopia, Syria, Turkey and Spain.

MAJOR PESTS				
Etiella zinckenella (Treit.)	Pea Pod Borer	Pyralidae	India	Larvae bore pods
Agrotis spp.	Cutworms	Noctuidae	India	Larvae are cutworms
Helicoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	India	Larvae eat young shoots & bore pods
Bruchus ervi Fröh	Lentil Beetle	Bruchidae	Mediterranean	Larvae bore seeds
MINOR PESTS				
Aphis craccivora Koch.	Groundnut Aphid	Aphididae	India	Infest foliage
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Widespread	Infest foliage
Diachrysia orichalcea (F.)	–	Noctuidae	India	Larvae eat leaves
Spodoptera exigua (Wlk.)	Lesser Armyworm	Noctuidae	India	Larvae eat leaves
Callosobruchus chinensis (L.)	Oriental Cowpea Bruchid	Bruchidae	India	Adults attack open pods in field

LETTUCE (*Lactuca sativa* – Compositae)

This is a native of S. Europe and W. Asia, and is descended from the wild lettuce (*L. scariola*), a common wasteland and roadside weed in both Old and New Worlds. It is another herbage vegetable of great antiquity; at the present time there are many varieties showing different horticultural characters. It has a milky sap and grows as a basal rosette of leaves, producing later in the season a stalk bearing the flowers. It has little food value in itself but does contain vitamins and iron salts. It grows best in a light sandy or loamy soil with a rather cool climate, and not too much sunshine; among the principal types grown are Cos, head, romains, and cut-leaf forms.

MAJOR PESTS				
Aphis gossypii Glov.	Melon/Cotton Aphid	Aphididae	Cosmopolitan	Infest foliage
Macrosiphum euphorbiae (Thos.)	Potato Aphid	Aphididae	Europe	Infest foliage
Myzus ascalonicus Don.	Shallot Aphid	Aphididae	Europe	Infest foliage
Myzus persicae (Sulz.)	Peach–Potato Aphid	Aphididae	Cosmopolitan	Infest foliage
Nasonovia ribis-nigri (Mosley)	Lettuce Aphid	Aphididae	Europe	Infest foliage
Pemphigus bursarius (L.)	Lettuce Root Aphid	Pemphigidae	Europe	Infest roots
MINOR PESTS				
Cnephasia spp.	Tortrix Moths	Tortricidae	Europe	Larvae defoliate
Agrotis segetum (D. & S.)	Common Cutworm	Noctuidae	Cosmopolitan in Old World	Larvae cutworms
Agrotis dahli (Hub.)	Cutworm	Noctuidae	Malaysia	Larvae are cutworms
Noctua pronuba (L.)	Large Yellow Underwing	Noctuidae	Europe	Larvae are cutworms
Plusia orichalcea	–	Noctuidae	S.E. Asia	Larvae defoliate

LITCHI (*Litchi chinensis* – Sapindaceae) (=Lychee)

A native of southern China, the Litchi is a dense polygamous tree, evergreen and up to 10 m high. It has been widely introduced throughout the tropics, but only flourishes at the higher altitudes. The tree is also used as an ornamental. The leaves are compound, elongate, leathery, and shiny with an indistinct venation. The fruit is distinctive; round, 2–5 cm in diameter, and is borne in loose clusters. The pericarp is bright red and leathery, becoming brown and brittle on drying; the translucent white flesh surrounds a single large seed. The fresh fruit is regarded as a great delicacy, especially in China, and some are now canned for the export trade. The main areas of production are China, Taiwan, Pakistan, Hawaii and India. (See also Butani, 1977.) .

MAJOR PESTS				
Tessaratoma papillosa (Dru.)	Litchi Stink Bug	Pentatomidae	S. China	Sap-sucker; toxic saliva
MINOR PESTS				
Odontotermes formosanus (Shir.)	Scavenging Termite	Termitidae	China, Taiwan	Workers damage tree
Aleurocanthus husaini Corbett	Blackfly	Aleyrodidae	India	Infest leaves
Aphis gossypii Glov.	Cotton Aphid	Aphididae	S. China	Infest shoots
Toxoptera aurantii (B. de F.)	Black Citrus Aphid	Aphididae	India	Infest shoots
Pseudococcus comstocki (Kuw.)	Comstock's Mealybug	Pseudococcidae	China, Japan, USA	Infest foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	India	Infest foliage
Aulacaspis spp.	Armoured Scales	Diaspididae	India	Infest foliage
Pyrops candelaria (L.)	Lantern Bug	Fulgoridae	S. China	Infest branches
Halys dentatus F.	Mulberry Bug	Pentatomidae	India	Sap-sucker; toxic saliva
Tessaratoma javanica Thnb.	Stink Bug	Pentatomidae	India	Sap-sucker; toxic saliva
Chrysocoris stolii (Wolff.)	Lychee Shield Bug	Pentatomidae	India }	Cause fruit-drop
Chrysocoris grandis Thnb.	Large White Shield Bug	Pentatomidae	China }	
Theniothrips distalis Karny	Thrips	Thripidae	India	Infest leaves & flowers
Indarbela spp.	Wood-borer Moths	Metarbelidae	China, India	Larvae eat bark & bore wood
Acrocercops spp.	Leaf-miners	Gracillariidae	India	Larvae mine leaves & damage fruits
Adoxophyes orana (F.R.)	Summer Fruit Tortrix	Tortricidae	S. China	Larvae eat leaves & fruit surface
Archips micaceana (Wlk.)	–	Tortricidae	S. China	Larvae roll leaves
Argyroploce illepida Butler	Seed (Fruit) Borer	Tortricidae	India	Larvae bore seeds
Cryptophlebia ombrodelta (Lower)	Macadamia Nut Borer	Tortricidae	China, Japan, USA S.E. Asia, India	Larvae bore fruits
Duchua aprobola (Meyr.)	Leaf Webber	Tortricidae	India	Larvae web shoots
Homona coffearia (Niet.)	Tea Tortrix	Tortricidae	S. China	Larvae roll leaves
Olethreutes leucaspis (Meyr.)	Litchi Leaf-roller	Tortricidae	China, India	Larvae roll leaves
Stauropus atternus Wlk.	Crab Caterpillar	Notodontidae	S. China	Larvae defoliate
Chlumetia transversa Wlk.	Mango Shoot Borer	Noctuidae	India	Larvae bore shoots
Lymantria mathura Moore	Tussock Moth	Lymantriidae	India	Larvae damage flowers & bark
Oecophylla smaragdina (F.)	Red Tree Ant	Formicidae	China, India	Nest in foliage; attack workers
Myllocerus spp.	Leaf Weevils	Curculionidae	India	Adults eat leaves
Amblyrrhinus poricollis Boh.	Plum Leaf Weevil	Curculionidae	India	Adults eat leaves
Aceria litchi (Keif.)	Litchi Gall Mite	Eriophyidae	India, China, Taiwan Hawaii	Young leaves galled & rolled

LONGAN (*Euphoria longana* – Sapindaceae)

A native of S. China, little cultivated away from this region. A dense evergreen tree up to 10 m tall, similar in appearance to Litchi but the leaf veins are prominent, the leaf less elongate, and the leaf surface rather rough. The fruit is smaller and less succulent than that of Litchi and it is grown for local consumption in China and Taiwan.

MAJOR PESTS				
Tessaratoma papillosa (Dru.)	Litchi Stink Bug	Pentatomidae	S. China, Laos, Malaysia	Sap-sucker; toxic saliva
MINOR PESTS				
Tachardina sp.	Forest Lac Insect	Lacciferidae	Malaysia	Infest twigs
Pyrops candelaria (L.)	Lantern Bug	Fulgoridae	S. China, Laos	Sap-sucker
Leptocentrus terminalis Wlk.	Treehopper	Membracidae	S. China	Infests twigs
Chelaria sp.	–	Gelechiidae	S. China	Larvae bore leaves
Clania spp.	Bagworms	Psychidae	Laos	Larvae defoliate
Olethreutes discana Feld.	Tortrix	Tortricidae	Laos	Larvae roll young leaves
Archips micaceana (Wlk.)	Tortrix	Tortricidae	Laos	Larvae roll leaves
Setora nitens (Wlk.)	Stinging Caterpillar	Limacodidae	Laos	Larvae eat leaves
Gen. & sp. indet.	Longan Gall Midge	Cecidomyiidae	S. China	Larvae gall leaves
Aspidomorpha sanctaecrusis F.	Tortoise Beetle	Chrysomelidae	Laos	Adults & larvae eat leaves
Adoretus tenuimaculatus Waterh.	Rose Beetle	Scarabaeidae	S. China	Adults eat leaves

LOQUAT (*Eriobotrya japonica* – Rosaceae)

One of the few tropical fruits belonging to the Rosaceae; it is a native of China, now grown in most tropical and subtropical countries. A small evergreen tree with broad leaves and fragrant white flowers. The fruits are round, small, downy and yellowish orange in colour. The flesh is rather tart and highly esteemed in the Orient where it has been grown since antiquity. The fruit is used fresh, and is made into jellies, sauces and pies. (See also Butani, 1974*a*.)

MAJOR PESTS (LOQUAT)				
Dacus dorsalis (Hend.)	Oriental Fruit Fly	Tephritidae	India	Larvae inside fruits
Indarbela quadrinotata Wlk.	Wood Boring Moth	Metarbelidae	India	Larvae eat bark & bore stems
MINOR PESTS				
Platypleura kaempferi (F.)	Speckled Brown Cicada	Cicadidae	S. Japan	Adults pierce trunk, cause sap exudation & fungus attack
Toxoptera aurantii (B. de F.)	Black Citrus Aphid	Aphididae	India	Infest foliage
Aphis malvae (Koch)	Mallow Aphid	Aphididae	India	Infest foliage
Chloropulvinaria psidii (Mask.)	Guava Mealy Scale	Coccidae	India	Infest foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	India	Infest foliage
Coccus viridis (Green)	Soft Green Scale	Coccidae	India	Infest foliage
Parlatoria spp.	Armoured Scales	Diaspididae	India	Infest twigs
Haplothrips sp.	Leaf-curling Thrips	Phlaeothripidae	India	Distort young leaves
Heliothrips sp.	Flower Thrips	Thripidae	India	Infest flowers
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	India	Larvae bore branches
Virachola isocrates F.	Anar Butterfly	Lycaenidae	India	Larvae bore fruits
Megachile anthracina Smith	Leaf-cutter Bee	Megachilidae	India	Adults defoliate
Adoretus spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves

MACADAMIA (*Macadamia ternifolia* – Proteaceae) (= Queensland Nut)

Macadamia nuts, also known as Queensland nuts being native to that part of Australia, are commercially the most expensive nuts known. The tree is small, some 5–10 m in height, and is now introduced into many parts of the tropical world, such as Kenya, Malawi and southern USA, and is of particular importance in Hawaii. Both thick-shelled and thin-shelled varieties are grown; the kernels are rich in oil and have a sweet flavour, and are generally regarded as the most delicious of nuts. Species currently being grown in Queensland are described as *M. tetraphylla* and *M. integrifolia*. (See also Ironside, 1973.)

MAJOR PESTS				
Eriococcus ironsidei Williams	Macadamia Felted Coccid	Eriococcidae	E. Australia	Distort young shoots
Amblypelta nitida Stal	Fruit-spotting Bug	Coreidae	E. Australia	Premature nut-fall & kernel damage
Amblypelta lutescens (Dist.)	Banana-spotting Bug	Coreidae	N. Australia	
Neodrepta luteotactella (Wlk.)	Macadamia Twig Girdler	Xyloryctidae	E. Australia	Larvae ring-bark twigs
Acrocercops chionosema Turner	Macadamia Leaf Miner	Gracillariidae	E. Australia	Larvae mine young leaves
Cryptophlebia ombrodelta (Lower)	Macadamia Nut Borer	Tortricidae	E. & N. Australia (India, Japan, S.E. Asia)	Larvae bore nuts & kernels
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Malawi	
Homoeosoma vagella Zell.	Macadamia Flower Caterpillar	Pyralidae	E. Australia	Larvae destroy flowers
MINOR PESTS				
Toxoptera aurantii (B. de F.)	Black Citrus Aphid	Aphididae	E. Australia	Damage developing racemes
Ulonemia concava Drake	Macadamia Lace Bug	Tingidae	S.E. Queensland	Adults & nymphs kill buds & flowers
Erysichton lineata (Murray)	Hairy Line Blue Butterfly	Lycaenidae	E. Australia	Larvae bore buds
Deudorix epijarbas diovis Hew.	Cornelian Butterfly	Lycaenidae	E. Australia	Larvae bore nuts
Isotenes miserana (Wlk.)	Orange Fruit Borer	Tortricidae	E. Australia	Larvae roll leaves; bore nuts
Comana fasciata (Wlk.)	Macadamia Cup Moth	Limacodidae	N. & E. Australia	Larvae defoliate
Anthela varia (Wlk.)	Variegated Hairy Caterpillar	Anthelidae	S.E. Queensland	Larvae defoliate
Dichocrocis punctiferalis (Guen.)	Yellow Peach Moth	Pyralidae	E. & N. Australia	Larvae tunnel nuts
Cateremna sp.	Macadamia Kernel Grub	Pyralidae	S.E. Queensland	Larvae damage kernels
Ephestia cautella (Wlk.)	Tropical Warehouse Moth	Pyralidae	S.E. Queensland	Larvae infest damaged nuts in storage
Lophodes sinistraria Guen.	Brown Looper	Geometridae	S.E. Queensland	Larvae defoliate
Olene mendosa (Hbn.)	Brown Tufted Caterpillar	Lymantriidae	S.E. Queensland	Larvae defoliate
Orgyia australis Wlk.	Macadamia Tufted Caterpillar	Lymantriidae	S.E. Queensland	Larvae defoliate
Nadiasa (Alenella) concava	Macadamia Tent Caterpillar	Lasiocampidae	Ethiopia	Larvae defoliate
Monolepta australis (Jac.)	Red-shouldered Leaf Beetle	Chrysomelidae	E. Australia	Adults damage foliage, flowers, young nuts

MAIZE (*Zea mays* – Gramineae) (= Sweet Corn, when unripe; Corn (in USA))

Maize originated in America and is now the principal cereal in the tropics and sub-tropics. It is also being grown for fodder and as a vegetable in Europe and northern N. America. It needs a good summer temperature for the grain to ripen, and grows best in lowlands with a good soil cover; it can withstand some drought once established. It is a tall, broad-leaved cereal; a single stem usually (4–5 m high in some varieties), with the male flower terminal and one or two cobs per stalk. Some varieties tiller more than others. The main production areas are S. America, parts of the USA, E. & S. Africa.

MAJOR PESTS				
Homorocoryphus nitidulus Wlk.	Grasshopper	Tettigoniidae	E. Africa	Defoliate
Patanga succincta (L.)	Bombay Locust	Acrididae	India, S.E. Asia	Defoliate
Cicadulina mbila Naude	Maize Leaf-hopper	Cicadellidae	E. & S. Africa	Sap-sucker; virus vector
Rhopalosiphum maidis (Fitch)	Corn Leaf Aphid	Aphididae	Cosmopolitan	Infest foliage
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Africa	Larvae damage cobs
Chilo partellus (Swinhoe)	Spotted Stalk Borer	Pyralidae	Africa, India, S.E. Africa	Larvae bore stalk
Chilo orichalcociliella (Strand)	Coastal Stalk Borer	Pyralidae	Africa	Larvae bore stalk
Chilo suppressalis (Wlk.)	Striped Rice Borer	Pyralidae	Spain, S.E. Asia, China, Japan, Australia	Larvae bore stalk
Eldana saccharina Wlk.	Sugarcane Stalk Borer	Pyralidae	Africa	Larvae bore stalk
Ostrinia nubilalis (Hb.)	European Corn Borer	Pyralidae	Europe, N. Africa, USA, S. Canada	Larvae bore stalk
Ostrinia fumacalis (Gn.)	Asiatic Corn Borer	Pyralidae	India, S.E. Asia, Japan, Australasia	Larvae bore stalk
Mrasmia trapezalis (Gn.)	Maize Webworm	Pyralidae	Pantropical	Larvae web leaves
Heliocoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	Cosmopolitan in Old World	Larvae feed on cobs
Heliocoverpa zea (Boddie)	Cotton Bollworm (Corn Earworm)	Noctuidae	N., C. & S. America	Larvae feed on cobs
Agrotis spp.	Cutworms	Noctuidae	Cosmopolitan	Larvae cutworms
Busseola fusca (Fuller)	Maize Stalk Borer	Noctuidae	Africa	Larvae bore stalk
Euxoa spp.	Cutworms	Noctuidae	N. America	Larvae cutworms
Sesamia calemistis Hmps.	Pink Stalk Borer	Noctuidae	Africa	Larvae bore stalk
Spodoptera exempta (Wlk.)	African Armyworm	Noctuidae	Africa, India, Australasia	Larvae defoliate
Mythimna unipuncta (Haw.)	Rice Armyworm	Noctuidae	Europe, E. & W. Africa, USA, C. & S. America	Larvae defoliate
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	S.E. Asia	Larvae defoliate
Atherigona soccata Rond.	Sorghum Shoot Fly	Muscidae	Africa, India	Larvae bore shoots
Atherigona oryzae Man.	Rice Shoot Fly	Muscidae	Malaysia	Larvae bore shoots
Delia platura (Meign.)	Bean Seed Fly	Anthomyiidae	USA, Europe	Larvae bore sown seeds
Schizonycha spp.	Chafer Grubs	Scarabaeidae	Africa	Larvae eat roots
Heteronychus spp.	Black Maize Beetles	Scarabaeidae	Africa, Australia	Adults bite stems underground
Epilachna similis (Thn.)	Epilachna Beetle	Coccinellidae	Africa, N. America	Adults & larvae eat leaves
Diabrotica spp.				
Monolepta bifasciata (Hornst.)	Maize Silk Beetle	Chrysomelidae	Philippines	Adults eat silks
Megalognatha rufiventris Baly	Maize Tassel Beetle	Chrysomelidae	E. Africa	Adults eat tassel and silks
Nematocerus spp.	Weevils	Curculionidae	Africa	Adults eat leaves
Sitophilus zeamais Mot.	Maize Weevil	Curculionidae	Cosmopolitan	Attack ripe seeds
Sitophilus oryzae L.	Rice Weevil	Curculionidae	S.E. Asia, Africa	in the field and in storage

(continued)

MINOR PESTS

Acheta testaceus Wlk.	Field Cricket	Gryllidae	S.E. Asia	Seedling pest
Gastrimargus marmoratus (Thnb.)	–	Acrididae	S.E. Asia	Defoliate
Hieroglyphus banian (F.)	Large Rice Grasshopper	Acrididae	S.E. Asia	Defoliate
Melanoplus spp.		Acrididae	USA	Defoliate
Phymateus aegrotus Gersi.	–	Acrididae	Africa	Defoliate
Oxya spp.	Small Rice Grasshoppers	Acrididae	S.E. Asia	Defoliate
Microtermes spp.	–	Termitidae	Africa	Collect plant material
Hodotermes mossambicus (Hagen)	Harvester Termite	Hodotermitidae	E. Africa	Defoliate
Cicadulina zeae China	Maize Leafhopper	Cicadellidae	Africa	Sap-sucker; virus vector
Graminella nigrifrons	Black-faced Leafhopper	Cicadellidae	S. USA	Sap-sucker; virus vector
Dalbulus maidis D. & W.	Corn Leafhopper	Cicadellidae	S. USA, C. & S. America	Sap-sucker, virus vector
Dalbulus spp.	Corn Leafhoppers	Cicadellidae	S. USA, C. & S. America	
Pyrilla perpusilla Wlk.	Indian Sugarcane Leafhopper	Lophopidae	India, Sri Lanka	Sap-sucker
Peregrinus maidis Ashm.	Maize Planthopper	Dephacidae	Pantropical	Sap-sucker
Laodelphax striatella (Fall.)	Small Brown Planthopper	Delphacidae	Europe, Asia	Sap-sucker; virus vector
Schizaphis graminum (Rond.)	Wheat Aphid	Aphididae	Old World	Sap-sucker
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	S.E. Asia	Sap-sucker; toxic saliva
Blissus leucopterus (Say)	Chinch Bug	Pentatomidae	Canada, USA	
Limothrips cerealium (Hal.)	Cereal Thrips	Thripidae	USA	
Frankliniella williamsi Hood	Flower Thrips	Thripidae	Thailand	Infest flowers
Chilo polychrysus (Meyr.)	Dark-headed Rice Borer	Pyralidae	India, S.E. Asia	Larvae bore stalks
Diatraea saccharalis (F.)	Sugarcane Borer	Pyralidae	N. & S. America	Larvae bore stalks
Nacoleia octasema (Meyr.)	Banana Scab Moth	Pyralidae	Indonesia, Australasia	Larvae damage cobs
Mythimna loreyi Dup.	Rice Armyworm	Noctuidae	E. Africa	Larvae damage cobs
Remigia repanda (F.)	Guinea Grass Moth	Noctuidae	C. & S. America	Larvae defoliate
Spodoptera exigua (Hub.)	Lesser Armyworm	Noctuidae	Thailand	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Asia, Australasia	Larvae defoliate
Spodoptera frugiperda (J.E. Smith)	Black Armyworm	Noctuidae	N., C. & S. America	Larvae defoliate
Sesamia cretica Led.	Sorghum Stalk Borer	Noctuidae	S. Europe, Africa, India	Larvae bore stalks
Sesamia inferens (Wlk.)	Purple Stem Borer	Noctuidae	Asia, Australasia	Larvae bore stalks
Sesamia nonagriodes (Lef.)	–	Noctuidae	Africa, Med.	Larvae bore stalks
Borbo cinnara (Wlk.)	Formosan Swift	Hesperiidae	S.E. Asia	Larvae roll leaves
Sitotroga cerealella (Ol.)	Angoumois Grain Moth	Gelechiidae	Cosmopolitan	Larvae attack ripe grains
Oscinella frit (L.)	Frit Fly	Chloropidae	Europe	Larvae gall stem
Delia arambourgi Seguy	Barley Fly	Anthomyiidae	Africa	Larvae destroy shoots
Carpophilus spp.	Corn Sop Beeths	Nitidulidae	Pantropical	
Mylabris spp.	Banded Blister Beetles	Meloidae	Europe, Africa, India, S.E. Asia	Adults eat flowers
Monolepta spp.	Corn Silk Beetles	Chrysomelidae	S.E. Asia	Adults eat silks
Diabrotica undecimpunctata Mann.	Spotted Cucumber Beetle	Chrysomelidae	N. America	Larvae bore stems underground; adults eat silks
Diabrotica spp.	Corn Rootworms	Chrysomelidae	N. America	

(continued)

Adoretus spp.	White Grubs (Rose Chafers)	Scarabaeidae	S.E. Asia	Larvae eat roots in soil; adults may damage flowers or leaves
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	
Leucophilis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	
Calomycterus sp.	Corn Seedling Weevil	Curculionidae	Thailand	Larvae kill seedlings
Graphognathus spp.	White-fringed Weevils	Curculionidae	Australia, USA, S. America	Larvae eat roots; adults leaves
Protostrophus spp.	Ground Weevils	Curculionidae	Africa	Adults eat foliage; larvae eat roots

MANGO (*Mangifera indica* – Anacardiaceae)

The centre of origin is the Indo-Burma region, and it grows wild in the forests of N.E. India; now it is grown widely throughout the tropics for fruit, and in the sub-tropics as an ornamental or shade tree. The main production areas are India, Florida, Egypt, Natal, the E. Africa coast, W. Indies and the Philippines. It is grown from sea-level to 1500 m, but grows best below 1000 m in climates with strongly marked seasons; dry weather is required for flowering. The tree is susceptible to frost, and the preferred temperature is 25–30°C. In habit it is a tree, large and evergreen, from 10–40 m in height, and can live for 100 years or more; fruit-bearing is often biennial. The fruit is a large, fleshy, delicious drupe, in size up to 20 cm long, yellow or red when ripe. The fruit is eaten fresh, or canned, and is also used in chutney and pickles to be eaten with curries.

MAJOR PESTS				
Idiocerus spp.	Mangohoppers	Cicadellidae	India, S.E. Asia	Cause flower-fall
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Infest foliage
Ceratitis cosyra (Wlk.)	Natal Fruit Fly	Tephritidae	Africa	Larvae in fruits
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	S.E. Asia	Larvae in fruits
Selenothrips rubrocinctus (Giard.)	Red-banded Thrips	Thripidae	Pantropical	Leaves scarified
Plocaederus spp.	Longhorn Beetles	Cerambycidae	Indo-China	Larvae bore trunk
Niphonoclea spp.	Mango Twig Borers	Cerambycidae	Philippines	Larvae bore twigs
Sternochetus mangiferae (F.)	Mango Seed Weevil	Curculionidae	S.E. Asia, India	Larvae bore seed in fruit
Deporaus marginatus (Pasc.)	Leaf Weevil	Curculionidae	Malaysia, Sri Lanka	Adults eat leaves
MINOR PESTS				
Microcerotermes edentatus Wasm.	–	Termitidae	E. Africa	Remove foliage
Idiocerus atkinsoni Leth.	Mangohopper	Cicadellidae	India	Infest shoots & flowers; cause fruit loss
Idiocerus clypealis Leth.	Mangohopper	Cicadellidae	India, Philippines	
Idiocerus nitidulus Wlk.	Mangohopper	Cicadellidae	Malaysia, Laos	
Apsylla cistellata Buckt.	Mango Shoot Psyllid	Psyllidae	India	Gall buds
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	Asia, S. America	Infest leaves
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	S.E. Asia, India, Africa, S. America	Infest foliage
Aspidiotus nerii Bche.	Oleander Scale	Diaspididae	Australasia, Africa, Asia	Infest foliage
Chrysomphalus aonidum (L.)	Purple Scale (Florida Red Scale)	Diaspididae	S.E. Asia	On leaves & twigs
Chrysomphalus dictyospermi (Morg.)	Spanish Red Scale	Diaspididae	Cosmopolitan	On leaves & twigs
Ischnaspis longirostris (Sign.)	Black Line Scale	Diaspididae	Pantropical	On leaves, shoots & fruits
Parlatoria crypta McKenz.	Mango White Scale	Diaspididae	India, Africa, Iran, Iraq	On leaves & shoots
Pseudaonidia trilobitiformis (Green)	Trilobite Scale	Diaspididae	Pantropical	Encrust foliage
Coccus mangiferae Green	Mango Soft Scale	Coccidae	India, Indonesia, Africa, S. America	On leaves & buds
Ceroplastes rubens Mask.	Pink Waxy Scale	Coccidae	E. Africa, Asia	Infest foliage
Chloropulvinaria psidii Mask.	Guava Scale	Coccidae	Pantropical	Infest foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	S.E. Asia	Infest foliage
Icerya purchasi Mask.	Cottony Cushion Scale	Margarodidae	S.E. Asia	Infest twigs & foliage
Icerya seychellarum Westw.	Seychelles Fluted Scale	Margarodidae	E. Africa, India, S.E. Asia, China, Japan	Infest twigs & foliage
Drosicha stebbingii Stebb.	Giant Mealybug	Margarodidae	S.E. Asia	Infest foliage
Drosicha mangiferae Green	Mango Giant Mealybug	Margarodidae	S.E. Asia, India, China	Infest foliage
Pseudotheraptus wayi Brown	Coconut Bug	Coreidae	E. Africa	Sap-sucker

(continued)

Mictis longicornis Westw.	Coreid Bug	Coreidae	Malaysia	Sap-sucker; toxic saliva
Indarbela spp.	Wood-boring Moths	Metarbelidae	India. SE Asia	Larvae eat bark
Orthaga incarusalis	Mango Webworm	Pyralidae	Malaysia, Laos	Larvae web flowers & fruits
Orthaga exvinacea Mi.	Mango Webworm	Pyralidae	India, Laos	
Clania spp.	Bagworms	Psychidae	Laos	Larvae defoliate
Autoba spp.	–	Noctuidae	Laos	Larvae attack flowers & leaves
Bombotelia jocosatrix Guen.	–	Noctuidae	Laos	Larvae defoliate
Heliocoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	Australasia	Larvae deflower
Othreis fullonia (Cl.)	Fruit-piercing Moth	Noctuidae	S.E. Asia	Adults pierce fruit
Chlumetia transversa (Wlk.)	Mango Shoot Borer	Noctuidae	Philippines	Larvae bore shoots
Parasa lepida Cram.	Blue-striped Nettlegrub	Limacodidae	S.E. Asia	Larvae defoliate
Attacus atlas (L.)	Atlas Moth	Saturniidae	Philippines	Larvae defoliate
Orgyia postica (Wlk.)	Tussock Moth	Lymantriidae	Laos, Philippines	Larvae attack flower stalks
Dacus zonatus Saund.	Peach Fruit Fly	Tephritidae	India	Larvae in fruit
Dacus cucurbitae Coq.	Melon Fly	Tephritidae	Philippines, India	Larvae in fruit
Anastrepha fraterculus (Wied.)	S. American Fruit Fly	Tephritidae	S. America	Larvae in fruit
Anastrepha mombinpraeoptans Sein.	West Indian Fruit Fly	Tephritidae	C. America	Larvae in fruit
Ceratitis capitata (Wied.)	Medfly	Tephritidae	Africa, Australia, C. & S. America	Larvae in fruit
Anastrepha ludens (Loew.)	Mexican Fruit Fly	Tephritidae	Mexico, C. America	Larvae in fruit
Erosomiyia indica Grov.	Mango Flower Gall Midge	Cecidomyiidae	India, Pakistan	Larvae damage flowers
Raodiplosis orientalis	Gall Midge	Cecidomyiidae	Burma, Laos	Larvae gall leaves
Oecophylla smaragdina (F.)	Red Tree Ant	Formicidae	India	Nest in foliage; attack workers
Monolepta bifasciata (Hornst.)	Corn Silk Beetle	Chrysomelidae	Philippines	Adults eat flowers
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots of seedlings
Pachnoda sinuata (F.)	Rose Beetle	Scarabaeidae	Africa	Adults eat flowers
Protaetia spp.	Rose Chafers	Scarabaeidae	Philippines	Adults attack fruits
Batocera rubus (L.)	White-spotted Longhorn	Cerambycidae	S.E. Asia, India, Mauritius	Larvae bore trunk
Batocera rufomaculatus (De Geer)	Red-spotted Longhorn	Cerambycidae	S.E. Asia, India	Larvae bore trunk
Plocaederus fulvicornis Guer.	Mango Bark Borer	Cerambycidae	Philippines	Larvae bore bark
Olenecamptus spp.	Longhorn Beetles	Cerambycidae	Laos	Larvae bore trunk
Deporaus marginatus (Pasc.)	Mango Leaf Weevil	Curculionidae	India, Sri Lanka	Adults eat leaves
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	S.E. Asia	Adults eat leaves
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Sternochetus frigidus F.	Mango Weevil	Curculionidae	S.E. Asia	Larvae in fruit pulp
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Pantropical	Distort leaves
Oligonychus mangiferus (R. & S.)	Mango Red Spider Mite	Tetranychidae	India	Damage leaves
Aceria mangifera Sayed	Mango Bud Mite	Eriophyidae	India	Distort buds

MANILA HEMP (*Musa textilis* – Musaceae) (= Abaca)

This is the world's premier cordage material, obtained from several species of wild banana. *Musa textilis* is the main species concerned and looks like the true banana, but with narrower leaves and small, inedible fruit. The fibre is made from the outer part of the leaf stalks. The crop is commercially important in the Philippines, Borneo and Sumatra, and now in parts of C. America.

MAJOR PESTS				
Cosmopolites sordidus Germ.	Banana Weevil	Curculionidae	S.E. Asia	Larvae bore rhizome
MINOR PESTS				
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Cosmopolitan	Infest foliage; virus vector
Pentalonia nigronervosa Coq.	Banana Aphid	Aphididae	S.E. Asia (Pantropical)	Infest leaf-bases
Nacoleia octasema (Meyr.)	Banana Scab Moth	Pyralidae	S.E. Asia	Larvae feed on flowers

MILLETS (Gramineae) (*Pennisetum typhoides* – Bulrush (Pearl) Millet) (*Panicum miliaceum* – Common Millet) (*Elusine coracana* – Finger Millet) (*Setaria italica* – Foxtail Millet) etc.

The millets are a somewhat heterogeneous assemblage of cereals with certain common characteristics, lumped together here for convenience. The four main species are listed above, but there are a few others not mentioned. Bulrush Millet is African in origin and is an important crop in Sudan, Nigeria, and around the southern edge of the Sahara. Finger Millet is native to E. Africa, and mostly grown India, but it is also grown widely in Africa south of the Sahara. All four species are grown extensively in India, and Foxtail Millet is in addition an important crop in China. Generally they are dry area crops, resistant to desiccation, and the grains store well. In the different regions of cultivation the different millets generally have quite similar pest spectra, but some important differences are evident.

MAJOR PESTS				
Zonocerus spp.	Variegated Grasshoppers	Acrididae	Africa	Defoliate & eat panicle
Pyrilla perpusilla Wlk.	Indian Sugarcane Leafhopper	Lophopidae	India	Suck sap
Laodelphax striatella (Fall.)	Small Brown Planthopper	Delphacidae	Europe, Asia	Suck sap
Taylorilygus vosseleri (Popp.)	Cotton Lygus	Miridae	Africa	Sap-sucker; toxic saliva
Chilo partellus (Swinh.)	Spotted Stalk Borer	Pyralidae	Africa, India, S.E. Asia	Larvae bore stalks
Sesamia calamistis Hamp.	Pink Stalk Borer	Noctuidae	Africa	Larvae bore stalks
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India	Larvae defoliate; destroy seedlings
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate; destroy seedlings
Atherigona soccata Rond.	Sorghum Shoot Fly	Muscidae	Africa, India	Larvae bore seedlings
Epilachna similis (Thnb.)	Epilachna Beetle	Coccinellidae	Africa	Adults & larvae eat foliage
Oulema spp.	Leaf Beetles	Chrysomelidae	Manchuria, China, India	Larvae mine leaves; adults strip leaves
MINOR PESTS				
Homorocoryphus nitidulus Wlk.	Edible Grasshopper	Tettigoniidae	E. Africa	Defoliate & eat panicle
Patanga succincta (L.)	Bombay Locust	Acrididae	India	Defoliate & eat panicle
Colemania sphenarioides Bol.	Deccan Wingless Grasshopper	Acrididae	India	Defoliate & eat panicle
Cicadulina spp.	Leafhoppers	Cicadellidae	India	Suck sap
Rhopalosiphum spp.	Cereal Aphids	Aphididae	India	Infest foliage
Schizaphis graminum Rond.	Wheat Aphid	Aphididae	India	Infest foliage
Peregrinus maidis Ashm.	Maize Planthopper	Delphacidae	India	Infest foliage
Leptocorisa acuta (Thnb.)	Rice Bug	Coreidae	India	Sap-sucker; toxic saliva
Nezara viridula L.	Green Stink Bug	Pentatomidae	India	Sap-sucker; toxic saliva
Bagrada hilaris (Burm.)	Harlequin Bug	Pentatomidae	Africa, India	
Anaphothrips sudanensis Trybom	Thrips	Thripidae	India, Africa	Infest foliage
Thrips hawaiiensis (Morg.)	Thrips	Thripidae	India	Infest foliage
Caliothrips indicus (Bagn.)	Thrips	Thripidae	India	Infest foliage
Amsacta spp.	Tiger Moths	Arctiidae	India	Larvae defoliate
Diacrisia obliqua Wlk.	Tiger Moth	Arctiidae	India	Larvae defoliate
Chilo infuscatellus Sn.	Yellow Top-borer	Pyralidae	Southern Asia	Larvae bore stem tops
Chilo orichalcociliella (Strand)	Coastal Stalk Borer	Pyralidae	Africa	Larvae bore stalks
Marasmia trapezalis Guen.	Maize Webworm	Pyralidae	India	Larvae web panicle
Helicoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	India, Africa	Larvae feed on panicle
Sesamia inferens Wlk.	Purple Stem Borer	Noctuidae	India	Larvae bore stalks
Sesamia nonagriodes (Lef.)	Rice Ear-cutting Caterpillar	Noctuidae	India	Larvae feed on panicle
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	India	Larvae feed on panicle

(continued)

Remigia repanda (F.)	Guinea Grass Moth	Noctuidae	C. & S. America	Larvae defoliate
Atherigona spp.	Shoot Flies	Muscidae	India	Larvae bore shoots
Itonida spp.	Gall Midges	Cecidomyiidae	India	Larvae in inflorescence
Holotrichia spp.	Chafer Grubs	Scarabaeidae	India	Larvae eat roots
Mylabris spp.	Banded Blister Beetles	Meloidae	Asia, Africa	Adults eat inflorescence
Epicauta spp.	Black Blister Beetles	Meloidae	Africa, India, USA	
Chaetocnema spp.	Flea Beetles	Chrysomelidae	India	Adults hole leaves
Nematocerus spp.	Nematocerus Weevils	Curculionidae	Africa	Adults eat leaves
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves

MULBERRY (*Morus* spp. – Moraceae)

Morus alba (White Mulberry) is native to China and grown to a limited extent in parts of the tropics for its edible fruits, for its leaves as food for silkworms, and for its wood used in making certain sports goods such as hockey sticks and tennis racquets. It is a small tree, up to 5 m in height, and the fruit is a syncarp.

Morus nigra (Black Mulberry) grows well only at higher elevations in the tropics; native to Iran. (See also Butani, 1978*c*.)

MAJOR PESTS

Pealius mori (Tak.)	Mulberry Whitefly	Aleyrodidae	Thailand	Infest leaves
Batocera rufomaculata (De Geer)	Red-spotted Longhorn	Cerambycidae	India, E. Africa, Malaysia	Larvae bore trunk
Apriona germari (Hope)	Jackfruit Longhorn	Cerambycidae	Thailand	Larvae bore branches

MINOR PESTS

Aleurolobus marlatti (Quaint.)	Marlatt Blackfly	Aleyrodidae	India	Infest foliage; sap-suckers
Icerya aegyptica (Dgl.)	Fluted Scale	Margarodidae	Africa, Asia	Infest foliage; sap-suckers
Drosicha mangiferae (Green)	Giant Mealybug	Margarodidae	India	Infest foliage; sap-suckers
Perissopneumon tamarinda (Green)	Mealybug	Pseudococcidae	India	Infest foliage; sap-suckers
Pseudococcus comstocki (Kum.)	Comstock's Mealybug	Pseudococcidae	Asia, China, Japan, USA	Infest foliage; sap-suckers
Maconellicoccus hirsutus (Green)	Mealybug	Pseudococcidae	Thailand, Laos	Infest shoots
Quadraspidiotus perniciousus (Comst.)	San José Scale	Diaspididae	India	Infest foliage; sap-suckers
Aonidiella aurantii (Mask.)	Red Scale	Diaspididae	India	Infest foliage; sap-suckers
Pseudaulacaspis pentagona (Targ.)	White Scale	Diaspididae	Cosmopolitan	Infest foliage; sap-suckers
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	India	Infest foliage; sap-suckers
Halys dentatus F.	Mulberry Bug	Pentatomidae	India	Sap-sucker; toxic saliva
Tryphactothrips rutherfordi Bagnall	Thrips	Thripidae	India	Infest leaves
Indarbela spp.	Wood-borer Moths	Metarbelidae	India, China	Larvae eat bark
Archips micaceana (Wlk.)	Leaf-roller	Tortricidae	Thailand	Larvae roll leaves
Exastema mori Mats.	Mulberry Leaf Roller	Tortricidae	Japan	Larvae roll leaves
Latoia lepida (Cramer)	Nettlegrub	Limacodidae	India	Larvae defoliate
Dichocrocis punctiferalis (Guen.)	Shoot Borer	Pyralidae	India	Larvae bore shoots
Spodoptera litura F.	Rice Cutworm	Noctuidae	India	Larvae eat leaves
Bombyx mori (L.)	Silkworm	Bombycidae	Laos	Larvae defoliate
Dacus tau (Wlk.)	Fruit Fly	Tephritidae	India, S.E. Asia	Larvae in fruits
Vespa spp.	Oriental Wasps	Vespidae	India, S.E. Asia	Adults pierce ripe fruits
Mimastra cyanema Hope	Almond Beetle	Chrysomelidae	India	Adults defoliate
Apriona cinerea Chevr.	Longhorn Beetle	Cerambycidae	India	Larvae bore trunk
Batocera spp.	Longhorns	Cerambycidae	India	Larvae bore trunk
Sthenias grisator F.	Stem-Girdler	Cerambycidae	S. India	Larvae girdle trunk
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	Thailand, Laos	Adults eat leaves

NUTMEG (*Myristica fragrans* – Myristicaceae)

This large evergreen tree, 10–20 m tall, is native to the Moluccas (or Spice Islands) but is now widely grown throughout the hot wet tropics. The ripe fruits are yellow and plum-like, and when ripe the husk splits open revealing the brown seed covered by the red, branching aril. The kernel of the seed is the nutmeg of commerce, and the aril is the source of the spice mace. The main production areas are the W. Indies (Granada), Indonesia and Malaysia.

MAJOR PESTS

Xyleborus fornicatus Eichh.	Tea Shot-hole Borer	Scolytidae	Malaysia	Adults bore branches
Phloeosomus cribratus Bland.	Shot-hole Borer	Scolytidae	Malaysia (Penang)	Adults bore branches

MINOR PESTS

Coccus mangiferae Green	Mango Soft Scale	Coccidae	Malaysia	Encrust leaves
Saissetia nigra (Nietn.)	Nigra Scale	Coccidae	India	Encrust leaves
Oryzaephilus mercator Fauv.	Merchant Grain Beetle	Cucujidae	Malaysia	Attack stored seeds
Araecerus fasciculatus (De Geer)	Nutmeg Weevil	Brenthidae	Cosmopolitan	Larvae bore inside the kernel; more important as a storage pest

OIL PALM (*Elaeis guineensis* – Palmae)

The centre of origin is western tropical Africa, where it is found wild. It is now established as a plantation crop in W. Africa, Malaysia, and Indonesia. It thrives only where rainfall is high, but will grow on poor soils. A typical palm tree in appearance, up to 10–15 m high at maturity. Fruit-bearing starts at five years, but full potential is not realized until the palm is ten years old. Oil is extracted from the mesocarp of the fruit; palm oil contains vitamin A; the oil is used in industry and to make soap. Kernel oil is of a higher quality and is used for margarine and other foodstuffs. The oil cake residue is used for livestock food. (See also Wood, 1968.)

MAJOR PESTS				
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	Pantropical	Infest foliage
Mahasena corbetti Tams	Coconut Case Caterpillar	Psychidae	S.E. Asia	Larvae defoliate
Rhynchophorus phoenicis (F.)	African Palm Weevil	Curculionidae	Africa	Larvae bore crown
Rhynchophorus ferrugineus (Oliv.)	Asiatic Palm Weevil	Curculionidae	India, S.E. Asia, Papua NG	Larvae bore crown
Rhynchophorus palmarum (L.)	South American Palm Weevil	Curculionidae	C. & S. America	Larvae bore crown
Diocalandra frumenti (F.)	Four-spotted Coconut Weevil	Curculionidae	E. Africa, India, S.E. Asia, Papua NG	Larvae bore plant body
Oryctes monoceros (Ol.)	Rhinoceros Beetle	Scarabaeidae	Africa	Adults damage crown
Oryctes rhinoceros (L.)	Rhinoceros Beetle	Scarabaeidae	Asia, Papua NG	
Rattus rattus	Black Rat	Muridae	S.E. Asia	Eat fruits
MINOR PESTS				
Brachytrupes spp.	Brown Crickets	Gryllidae	S.E. Asia	Important pests in nurseries
Gryllotalpa spp.	Mole Crickets	Gryllotalpidae	S.E. Asia	
Aularches miliaris L.	Spotted Grasshopper	Acrididae	Thailand	Adults and nymphs eat leaves
Valanga nigricornis (Burm.)	–	Acrididae	Malaysia	
Gastrimargus marmoratus (Thnb.)	–	Acrididae	Malaysia	
Coptotermes curvignathus Holmg.	–	Rhinotermitidae	Malaysia	Workers tunnel live trunk
Ricania speculum Wlk.	Black Planthopper	Ricaniidae	Malaysia	Suck sap
Cerataphis lataniae Boisd.	Latania Aphid	Aphididae	Malaysia	Suck sap; infest foliage
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	Malaysia	Infest foliage
Pseudococcus spp.	Mealybugs	Pseudococcidae	Malaysia	Infest fruits & foliage
Pinnaspis buxi (Bch.)	–	Diaspididae	Pantropical	Infest foliage
Ischnaspis longirostris (Sign.)	Black Line Scale	Diaspididae	Pantropical	Infest foliage
Chrysomphalus dictyospermi (Morg.)	Spanish Red Scale	Diaspididae	Pantropical	Infest foliage
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	Malaysia	Sap-sucker; toxic saliva
Artona catoxantha (Hmps.)	Coconut Leaf Skeletonizer	Zygaenidae	Thailand	Larvae skeletonize leaves
Tirathaba mundella Wlk.	Oil Palm Bunch Moth	Pyralidae	Malaysia, Sumatra	Larvae feed on fruit bunches
Pimelephila ghesquierei Tams	Palm Moth	Pyralidae	Africa (Zaïre)	Larvae bore leaves
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Malaysia	Larvae eat leaves

(continued)

Parasa vivida (Wlk.)	Nettlegrub	Limacodidae	Africa	Larvae with protruding setae with urticating properties; larvae defoliate
Parasa lepida Cramer	Nettlegrub	Limacodidae	Thailand	
Setora nitens Wlk.	Nettle Caterpillar	Limacodidae	S.E. Asia	
Thosea sinensis Wlk.	Nettle Caterpillar	Limacodidae	Thailand, Sumatra	
Cremastopsyche pendula Joannis	Bagworm	Psychidae	S.E. Asia	Larvae are bagworms & construct cases from plant leaf material; defoliators
Clania spp.	Bagworms	Psychidae	S.E. Asia	
Metisa plana Wlk.	Bagworm	Psychidae	S.E. Asia	
Erionota thrax L.	Banana Skipper	Hesperiidae	Thailand, Malaysia	Larvae cut leaf rolls
Hidari irava Moore	Leaf-binder	Hesperiidae	Thailand	Larvae fold leaves
Lotongus calathus How.	Leaf-binder	Hesperiidae	Thailand	Larvae fold leaves
Cephrenes chrysozona Plotz.	Skipper	Hesperiidae	Malaysia	Larvae fold leaves
Dasychira spp.	Tussock Moths	Lymantriidae	S.E. Asia	Larvae defoliate
Orgyia turbata Butler	Tussock Moth	Lymantriidae	Malaysia	Larvae defoliate
Pachnoda spp.	Rose Beetles	Scarabaeidae	Africa	Adults eat leaves of young palms; serious in nurseries
Adoretus spp.	Flower Beetles	Scarabaeidae	Malaysia, Sumatra	
Apogonia spp.	Brown Flower Beetles	Scarabaeidae	Malaysia, Sumatra	
Xylotrupes gideon L.	Unicorn Beetle	Scarabaeidae	Malaysia	Adults gnaw foliage
Leucopholis rorida (F.)	White Grub	Scarabaeidae	Malaysia, Sumatra	Larvae eat roots
Straegus aloeus L.	–	Curculionidae	C. & S. America	Larvae bore plant
Temnoschoita quadripustulata Gyll.	–	Curculionidae	Africa	Larvae bore plant
Coelaenomenodera elaeidis Wlk.	Leaf Miner	Chrysomelidae	W. & C. Africa	Larvae mine leaves, adults eat long strips of leaf material
Hispoleptis elaeidis	Leaf Miner	Chrysomelidae	Ecuador	
Promecotheca cumingi Baly	Leaf Miner	Chrysomelidae	Malaysia	
Plesispa reichei Chapuis	Coconut Hispid	Chrysomelidae	Thailand	
Atta spp.	Leaf-cutting Ants	Formicidae	C. & S. America	Remove leaf material
Xyleborus similis Ferrari	Shot-hole Borer	Scolytidae	Thailand	Adults bore plant
Oligonychus spp.	Red Spider Mites	Tetranychidae	Malaysia	Adults & nymphs scarify leaves
Tetranychus spp.	Red Spider Mites	Tetranychidae	Malaysia	
Retrachus elaeis	Oil Palm Mite	Eriophyidae	C. & S. America	Make black blotches on leaves

OKRA (*Hibiscus esculentus* – Malvaceae) (= Ladies' Fingers)

Okra is native to tropical Africa but is now widespread throughout the tropics. It grows well in the lowland tropics on most types of soil, but the best crops are produced on well-manured loams. The plant is a robust erect herb 1–2 m tall, and the fruit is a beaked pyramidal capsule 10–30 cm long by 2–3 cm broad, with a high mucilage content, and is used as a vegetable either boiled or fried. The ripe seeds contain 20% edible oil. Okra is grown on a pantropical basis, but mostly for local fresh consumption; a little canning is done, and some are exported to Europe.

MAJOR PESTS				
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Cosmopolitan	Infest foliage
Empoasca spp.	Green Leafhoppers	Cicadellidae	S.E. Asia, Africa, India	Sap-suckers on leaves
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	S.E. Asia, India	Infest foliage
Dysdercus spp.	Cotton Stainers	Pyrrhocoridae	S.E. Asia, Africa	Suck sap from seeds
Oxycarenus hyalipennis Costa	Cotton Seed Bug	Lygaeidae	India, S.E. Asia, Africa	Suck sap from seeds
Earias vittella Stoll.	Spiny Bollworm	Noctuidae	Malaysia	} Larvae attack & bore fruit capsules
Earias biplaga Wlk.	Spiny Bollworm	Noctuidae	Africa	}
Earias insulana (Boisd.)	Spiny Bollworm	Noctuidae	India, S.E. Asia, Africa	}
Heliocoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	Cosmopolitan in Old World	}
MINOR PESTS				
Atractomorpha crenulata F.	Grasshopper	Acrididae	India	Defoliate
Heteroplernis obscurella	Grasshopper	Acrididae	Papua NG	Defoliate
Amrasca biguttula (Ishida)	Leafhopper	Cicadellidae	India	Sap-sucker
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Philippines, India	} On leaves & stems
Coccus spp.	Solt Green Scales	Coccidae	Pantropical	}
Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	India	Infest foliage; virus vector
Colgar sp.	Moth Bug	Flattidae	Papua NG	Sap-sucker
Calidea dregii Germ.	Blue Bug	Pentatomidae	Africa	Sap-sucker; toxic saliva
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	S.E. Asia	Sap-sucker; toxic saliva
Tarundia glaucesenus	Planthopper	Ricaniidae	Papua NG	Sap-sucker
Frankliniella sulphurea Schmutz	Thrips	Thripidae	India	Infest flowers
Thrips tabaci Lind.	Onion Thrips	Thripidae	India	Infest flowers
Pectinophora gossypiella (Saund.)	Pink Bollworm	Gelechiidae	Cosmopolitan	Larvae bore fruits
Homona coffearia (Nietn.)	Tea Tortrix	Tortricidae	Papua NG	Larvae roll leaves
Adoxophyes sp.	Leaf Roller	Tortricidae	Papua NG	Larvae roll leaves
Sylepta derogata (F.)	Cotton Leaf Roller	Pyralidae	S.E. Asia, India, Africa	Larvae roll leaves
Zeuzera coffeae Nietn.	Red Coffee Borer	Cossidae	Philippines	Larvae bore stems
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	India	Larvae are cutworms
Acontia spp.	–	Noctuidae	India	Larvae eat foliage
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	S.E. Asia, India, Australasia	Larvae eat foliage
Spodoptera littoralis (Boisd.)	Cotton Leaf-worm	Noctuidae	Africa	Larvae defoliate
Xanthodes transversus	–	Noctuidae	Papua NG	Larvae defoliate
Chrysodeixis chalcites (Esp.)	Cabbage Semilooper	Noctuidae	Malaysia	Larvae defoliate
Anomis flava (F.)	Cotton Semilooper	Noctuidae	Old World tropics	Larvae defoliate
Latoia lepida (Cram.)	Blue-striped Nettlegrub	Limacodidae	Philippines	Larvae defoliate
Solenopsis geminata (F.)	Fire Ant	Formicidae	Philippines	Attack workers
Mylabris spp.	Banded Blister Beetles	Meloidae	India, S.E. Asia, Europe, Africa	Adults deflower
Anomala spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots

(continued)

Oxycetonia spp.	Rose Chafers	Scarabaeidae	India	Adults eat flowers
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Holotrichia insularis Brenske	White Grub	Scarabaeidae	India	Larvae eat roots
Epilachna spp.	Epilachna Beetles	Coccinellidae	S.E. Asia	Adults & larvae eat leaves
Podagrica bowringi B.	Flea Beetle	Chrysomelidae	India	Adults hole leaves
Nisotra gemella Erichs.	Flea Beetle	Chrysomelidae	Philippines	Adults hole leaves
Monolepta bifasciata Hornst.	Corn Silk Beetle	Chrysomelidae	Philippines	Adults eat leaves
Agrilus acutus Thnb.	–	Buprestidae	S.E. Asia	
Paratrachys sp.	Jewel Beetle	Buprestidae	India	Larvae bore stems
Trachys herilla Obenb.	Jewel Beetle	Buprestidae	India	
Sphenoptera gossypii Banks	Cotton Stem Borer	Buprestidae	India	
Alcidodes affaber F.	Stem-girdling Weevil	Curculionidae	India	Adults eat shoots; larvae bore stems
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves; larvae eat roots

OLIVE (*Olea europaea* – Oleaceae)

The Olive is one of the oldest of fruits and has been grown since prehistoric times. It was known in Egypt in the 17th century BC. It is widely cultivated throughout the Mediterranean region and has now been introduced extensively throughout the tropics and sub-tropics. The main areas of commercial production are California, Spain, Italy, Portugal, Turkey, Tunisia and Greece. The fruits have a high oil content, and are eaten both green and when ripe (black), but are most important as the source of olive oil. The tree is a small evergreen 8–12 m in height, with small leathery leaves. A deep fertile soil is required, together with temperatures of about 14°C (average) and not falling below −10°C. Irrigation is often required for successful groves.

MAJOR PESTS				
Parlatoria oleae (Colv.)	Olive Scale	Diaspididae	Cosmopolitan	Encrust & kill twigs
Saissetia oleae (Bern.)	Black Scale	Coccidae	Cosmopolitan	Encrust foliage
Dacus oleae (Gmel.)	Olive Fruit Fly	Tephritidae	Med., S. Africa	Larvae in fruits
MINOR PESTS				
Aphis spiraecola Patch	Apple Aphid	Aphididae	Cosmopolitan	Infest foliage
Euphyllura olivina Costa	Olive Psyllid	Psyllidae	Med. Ethiopia	Sap-suckers; infest leaf axils
Aleurolobus olivinus Silv.	Olive Whitefly	Aleyrodidae	Italy, Africa	Infest foliage
Ceroplastes rusci (L.)	Fig Wax Scale	Coccidae	Med.	Infest foliage
Aspidiotus nerii Bch.	Oleander Scale	Diaspididae	Cosmopolitan	Encrust twigs
Pleorochila (Teleonemia) australis Dist.	Lace Bug	Tingidae	Ethiopia, S. Africa	Sap-sucker; distort leaves
Dasyneura oleae (Lw.)	Olive Midge	Cecidomyiidae	Med.	Larvae make leaf galls
Ceratitis capitata (Wied.)	Mediterranean Fruit Fly	Tephritidae	Cosmopolitan	Larvae in fruits
Liothrips oleae Costa	Olive Thrips	Thripidae	Med., Africa	Infest foliage
Prays oleae F.	Olive Moth	Yponomeutidae	Med., S. Africa	Larvae bore fruits
Cacoecimorpha pronubana Hb.	Carnation Leaf-roller	Tortricidae	Med., Europe	Larvae roll leaves
Palpita unionalis (Hb)		Pyralidae	Med.	Larvae eat leaves
Metriochroa latifoliella (Milliere)	–	Gracillariidae	Med.	Larvae mine leaves
Acherontia atropos L.	Death's Head Hawk Moth	Sphingidae	Europe, Africa, S.E. Asia	Larvae defoliate
Hyles lineata (F.)	Silver-striped Hawk Moth	Sphingidae	Med.	Larvae defoliate
Zeuzera pyrina L.	Leopard Moth	Cossidae	Med.	Larvae bore branches
Apate monachus F.	Black Borer	Bostrychidae	Med.	Adults bore branches
Otiorhynchus cribricollis Gylh.	Apple Weevil	Curculionidae	Med., W. USA, Australia	Larvae eat roots; adults eat leaves
Rhynchites cribripennis (Desbr.)	Twig Cutter	Curculionidae	Med.	Adults cut twigs
Mylabris oleae Chevr.	Olive Blister Beetle	Meloidae	N. Africa	Adults eat flowers
Asterodiaspis minus	Oak Pit Scale	Asterolecaniidae	Holaretic	Female in pits on twigs
Eurytoma spp.	Olive Seed Chalcids	Eusytomidae	S. Africa	Larvae eat kernel

ONIONS (*Allium* spp. – Amaryllidaceae) (Onions, Shallot, Garlic, Chives, Leek)

Onions are a crop of great antiquity, unknown in the wild state, but probably originating in S. Asia, or the Mediterranean region. They are mainly temperate crops but are quite widely grown in sub-tropical areas, and also in some parts of the tropics, although they generally prefer light sandy soils in cool moist regions. Onions are grown either as bulbs for drying (ware onions), or for pickling, or as salad onions. Leeks are more temperate and grown as a vegetable for cooking. Garlic and chives are used in cooking for flavouring and garnishing purposes; the local equivalents in the Far East are different species from the European ones. (See also Butani & Varma, 1976*b*.)

MAJOR PESTS				
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Infest leaves
Delia antiqua (Meign.)	Onion Fly	Anthomyiidae	Cosmopolitan	Larvae inside bulb
Delia platura (Meign.)	Bean Seed Fly	Anthomyiidae	Cosmopolitan	Larvae destroy seed or invade bulb
Spodoptera exigua (Hub.)	Beet Armyworm	Noctuidae	S. Europe, Asia	Larvae eat leaves
MINOR PESTS				
Euborellia annulipes Lucas	Earwig	Forficulidae	India	Damage seedlings
Myzus ascalonicus Don.	Shallot Aphid	Aphididae	Europe	Infest foliage sucks sap and virus vectors
Myzus persicae (Sulz.)	Peach–Potato Aphid	Aphididae	Cosmopolitan	
Lipaphis erysimi (Kalt.)	Turnip Aphid	Aphididae	Cosmopolitan	
Aeolothrips spp.	Thrips	Aeolothripidae	India	Infest foliage
Caliothrips indicus (Bag.)	Groundnut Thrips	Thripidae	India	
Acrolepia assectella (Zell.)	Leek Moth	Yponomeutidae	Europe, Asia	Larvae defoliate
Cnephasia spp.	–	Tortricidae	Europe	Larvae defoliate
Noctua pronuba (L.)	Large Yellow Underwing	Noctuidae	Europe	Larvae are cutworms
Agrotis ipsilon (Roth.)	Black Cutworm	Noctuidae	Cosmopolitan	
Heliothis assulta	–	Noctuidae	Papua NG	Larvae defoliate
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	Old World	Larvae inside leaves
Spodoptera litura F.	Rice Cutworm	Noctuidae	India, S.E. Asia	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa, S. Europe	Larvae defoliate
Phytobia cepae (Her.)	Onion Leaf Miner	Agromyzidae	C. Europe, Malaya, China, Japan	Larvae mine leaves
Anthrenus spp.	–	Dermestidae	India	Attack stored bulbs
Aceria tulipae (K.)	Onion Mite	Eriophyidae	USA	Infest bulb

OPIUM POPPY (*Papaver somniferum* – Papaveraceae)

Opium is one of the oldest narcotics known to man, originating probably in Asia Minor, and mostly cultivated in this region, and parts of India, S.E. Asia and China. Opium is actually the dried exudate (juice) from injured capsules of the opium poppy. Properly utilized, optium and its alkaloid derivatives (morphine, and heroin) are invaluable to mankind medicinally for the relief of pain. However, this drug had been used for centuries as a narcotic and its inevitable abuse leads to habituation and both physical and mental deterioration and degradation. Thus its cultivation is subject to rigorous international legislation in most parts of the world.

MAJOR PESTS				
Mamestra brasicae	Cabbage Moth	Noctuidae	Europe	Larvae defoliate
Stenocarus fuliginosus	Poppy Root Weevil	Curculionidae	Romania	Larvae eat roots
Curculio spp.	Root Weevils	Curculionidae	Balkans	Larvae bore roots

MINOR PESTS				
Chrotogonus sp.	Surface Grasshopper	Acrididae	India	Defoliate
Aphis fabae Scop.	Black Bean Aphid	Aphididae	Europe	Infest foliage
Frankliniella sulphurea Schm.	Flower Thrips	Thripidae	India	Infest flowers
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	India	Larvae are cutworms
Agrotis segetum (Schff.)	Common Cutworm	Noctuidae	India	Larvae are cutworms
Helicoverpa armigera Hb.	Old World Bollwarm	Noctuidae	India	Larvae bore capsule
*Trichop*lusia ni.	Cabbage Semllooper	Noctuidae	India	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India	Larvae defoliate
Dasyneura papaveris (Winn.)	Poppy Capsule Midge	Cecidomyiidae	Europe (not UK) Turkey	Larvae infest capsules
Carpodiplosis papaveris Kjell.	–	Cecidomyiidae	Europe (not UK)	Larvae in capsule wall
Phytomyza horticola	Pea Leaf miners	Agromyzidae	UK	Larvae mine leaves
Tenthredo dahlii	Flower Sawfly	Tenthrodinidae	Balkans	Larvae eat flowers
Pachycephus smymensis	–	Cephidae	Greece	Larvae eat flowers
Ceutorhynchus albovittatus	Capsule Weevil	Curculionidae	Greece, Yugoslavia	Larvae in capsule
C. maculaalba	Capsule Weevil	Curculionidae	Romania	

PAPAYA (*Carica papaya* – Caricaceae) (= Pawpaw; Papita)

Papaya has never been found wild, but probably originated in S. Mexico and Costa Rica. It was spread to the W. Indies and Philippines in the 16th century, and to E. Africa by the 19th century. It is essentially a tropical plant, grown mainly between 32°N and 32°S, and is killed by frost. It can be grown from sea-level to 2000 m near the Equator, and it needs sunshine and high temperatures, with well-drained soil. It can be grown under irrigation. The plant is a short-lived, quick-growing, fleshy tree with few branches, 2–10 m tall. Latex vessels run in all parts of the plant body. The fruit is a large fleshy berry 7–30 cm in length, weighing up to 9 kg, oblong to spherical in shape, yellow when ripe. The edible reddish flesh is eaten for breakfast and dessert, also for jams, flavouring and canning; papain, a proteolytic enzyme, is extracted and used for tenderizing meat. The fruit has a high vitamin A and B content.

MAJOR PESTS				
Planococcus citri Risso	Root Mealybug	Pseudococcidae	Pantropical	Encrust leaves & fruits
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Encrust leaves & fruits
Ceratitis capitata (Wied.)	Medfly	Tephritidae	Africa, C. & S. America, Med.	Larvae inside fruits
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	India, China, Hawaii	Scarify foliage

MINOR PESTS				
Poecilocerus pictus F.	Ak Grasshopper	Acrididae	India	Defoliate
Gryllotalpa africana Pal.	African Mole Cricket	Gryllotalpidae	S.E. Asia	Attack roots
Empoesca papayae Oman.	Papaya head hopper	Cicadellidoe	S. America	Infest foliage; virus vector
Aphis gossypii Glov.	Cotton Aphid	Aphididae	India	Sap-suckers; vector of Papaya Mosaic Virus disease
Pergandeida robiniae Macc.	–	Aphididae	Pantropical	(as above)
Myzus persicae (Sulz.)	Green Peach Aphid	Aphididae	Cosmopolitan	(as above)
Aphis Spiraecola patch	Spirea Aphid	Aphididae	Cosmopolitan	Virus vector
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Philippines	Infest foliage
Drosicha mangiferea Green	Mango Giant Mealybug	Margarodidae	India	Encrust leaves
Saissetia nigra (Nietn.)	Nigra Scale	Coccidae	Philippines	Infest leaves
Aspidiotus orientalis New.	Oriental Scale	Diaspididae	Malaysia, China	Encrust foliage
Aonidiella orientalis New.	Oriental Yellow Scale	Diaspididae	Pantropical	Encrust foliage
Morganella longispina Morg.	–	Diaspididae	Pantropical	Infest foliage
Amblypelta Cocophaga China	Coconut Bug	Coreidae	Pacific	Saliva toxic, spot fruits
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	Philippines	Larvae in fruit
Dacus ferrugineus F.	Fruit Fly	Tephritidae	Malaysia	Larvae in fruit
Dacus pedestris Bezzi	Fruit Fly	Tephritidae	India, Sri Lanka	Larvae in fruit
Toxotrypana curvicauda Gerst.	Fruit Fly	Tephritidae	India, S. America	Larvae in fruit
Ptecticus elongatus F.	–	Therevidae	E. Africa	Larvae in fruit
Dichocrosis punctiferalis (Guen.)	Leaf-folder	Pyralidae	Philippines	Larvae fold leaf
Diacrisia investigatorum Karsch.	Tiger Moth	Arctiidae	Africa	Larvae defoliate
Othreis fullonia (Cl.)	Fruit-piercing Moth	Noctuidae	Old World tropics	Adults pierce fruits
Rhabdoscelis obscurus Boisd.	Cane Weevil Borer	Curculionidae	Australasia, Fiji, Hawaii, W. Indies	Larvae bore stem
Protaetia spp.	Rose Chafers	Scarabaeidae	S.E. Asia	Adults attack ripe fruits
Dihammus vastator Newm.	Longhorn Beetle	Cerambycidae	Philippines	Larvae bores stem
Brevipalpus phoenicis (Geij.)	Red Crevice Mite	Tenuipalpidae	Hawaii	Scarify foliage
Tenuipalpus bioculatus McG.	–	Tenuipalpidae	Hawaii	Scarify foliage
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Hawaii	Scarify foliage
Vespa/Polistes spp.	Wasps	Vespidae	Pantropical	Adults hole ripe fruits

PASSION FRUIT (*Passiflora edulis* – Passifloraceae) (*P. quadrangularis*) (= Grenadilla & Giant Granadilla)

These are both native to S. America, the latter species being grown mostly for local consumption. Both are now pantropical in distribution. They are grown commercially in S. Africa, Kenya, Australia, New Zealand, and Hawaii. The former species occurs as two varieties, one purple and the other yellow in colour. The plant body is a vigorous woody perennial climber, up to 15 m long. The purple passion fruit does best in the highlands of the tropics, whereas the yellow variety tolerates lower altitudes. In regions of heavy rainfall, however, pollination is often poor; a rainfall of less than 80 cm is preferred, and it will grow on most soils so long as they are not waterlogged. The globular fleshy berry is eaten fresh, but there is now a great demand for passion fruit juice which is delicious in taste and very rich in vitamin C.

MAJOR PESTS

Planococcus citri (Risso)	Citrus Mealybug	Pseudococcidae	Australia	
Planococcus kenyae (Le Pell.)	Kenya Mealybug	Pseudococcidae	E. & W. Africa	Encrust foliage
Ceratitis capitata (Wied.)	Medfly	Tephritidae	Africa, Hawaii	Larvae inside fruit
Dacus umbrosus F.	Fruit Fly	Tephritidae	Malaysia	Larvae in fruit
Brevipalpus phoenicis (Geijskes)	Red Crevice Tea Mite	Tenuipalpidae	Pantropical	Invest foliage, may kill branches.

MINOR PESTS

Coccus hesperidum L.	Helmet Scale	Coccidae	Australia	Infest foliage
Scolypopa australis Wlk.	Planthopper	Ricaniidae	Australia	Infest foliage
Aphis gossypii Glov.	Cotton Aphid	Aphididae	S.E. Asia, Australia	Infest foliage
Macrosiphum euphorbiae (Ths.)	Potato Aphid	Aphididae	S.E. Asia	Infest foliage
Aonidiella aurantii (masrk.)	Red Scale	Diaspididae	Australia	
Pseudaonidia trilobitiformis (Green)	Trilobite Scale	Diaspididae	Pantropical	Encrust foliage
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	S.E. Asia, Kenya	Sap-sucker; toxic saliva
Clavigralla tomentosicollis	Spiny Brown Bug	Coreidae	Africa	
Megymenum brevicorne F.	Shield Bug	Pentatomidae	Malaysia	Sap-sucker; toxic saliva
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Australia	
Ceratitis catoirii G.-M.	Fruit Fly	Tephritidae	Mauritius	Larvae in fruits
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	S.E. Asia, Hawaii	Larvae in fruits
Dacus cucurbitae Coq.	Melon Fly	Tephritidae	S.E. Asia, Hawaii	Larvae in fruits
Dacus tryoni (Fross.)	Queensland F.F.	Tephritidae	Australia	Larvae in fruits
Agraulis vanillae (L.)	Vanilla Butterfly	Nymphalidae	Hawaii, Colombia	Larvae eat leaves
Porthesia scintillans Wlk.	Tussock Moth	Lymantriidae	Malaysia	Larvae defoliate
Heliothrips haemorrhoidalis (Bouché)	Black Tea Thrips	Thripidae	S.E. Asia	Infest foliage
Dihammus vastator Newm.	Longhorn Beetle	Cerambycidae	Australia	Larvae bore vines
Tetranychus marianae McG.	Spider Mite	Tetranychidae	Pacific, C. & S. America	Scarfy foliage

PEA (*Pisum sativum* – Leguminosae) (Garden Pea; Field Pea)

The common pea is native to S. Europe and has been cultivated since prehistoric times, and was taken to America by the earliest colonists. Although indigenous to warm climates, it grows well under cool, moist, summer conditions, and thrives in N. Europe, N. America and Canada. The two main groups of varieties are Field Peas, grown for their dried seeds, the plants used for silage, forage and green manuring, and Garden Peas grown as a vegetable, the seeds eaten green, either fresh or frozen, or used in canning, and in some varieties the young pod is cooked whole. The plant body is used as livestock feed. Most peas are now grown as field crops, with a bushy habit, and harvested mechanically. Peas are important field and garden crops in all temperate countries, and in some tropical countries, at high altitudes or in the cool season.

MAJOR PESTS

Acyrthosiphon pisum (Harris)	Pea Aphid	Aphididae	Cosmopolitan	Infest foliage
Cydia nigricana (F.)	Pea Moth	Tortricidae	Europe, USA, Canada	Larvae in pods
Maruca testulalis (Geyer)	Mung Moth	Pyralidae	Pantropical	Larvae bore pods
Etiella zinckenella (Triet.)	Pea Pod Borer	Pyralidae	Pantropical	Larvae bore pods
Contarinia pisi (Winn.)	Pea Midge	Cecidomyiidae	Europe	Larvae infest shoots
Delia platura (Meig.)	Bean Seed Fly	Anthomyiidae	Cosmopolitan	Larvae destroy seed in soil
Apion spp.	Apion Weevils	Apionidae	Cosmopolitan	Adults infest flowers

MINOR PESTS

Aphis craccivora Koch.	Groundnut Aphid	Aphididae	Cosmopolitan	Infest foliage
Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	India	Infest foliage
Empoasca spp.	Green Leaf-hoppers	Cicadellidae	Cosmopolitan	Infest foliage
Creontiades spp.	Capsid Bugs	Miridae	India	Sap-suckers
Thrips angusticeps Uzel	Cabbage Thrips	Thripidae	Europe	Infest flowers & shoots
Kakothrips robustus (Uzel)	Pea Thrips	Thripidae	Europe	Scarifies young pods
Cnephasia spp.	Leaf-rollers	Tortricidae	Europe	Larvae roll leaves
Adoxophyes sp.	Leaf-roller	Tortricidae	Papua NG	Larvae roll leaves
Leucinodes orbonalis Gn.	Eggplant Boring Caterpillar	Pyralidae	India	Larvae bore shoots
Lampides boeticus (L.)	Pea Blue Butterfly	Lycaenidae	Asia }	Larvae bore pods to eat seeds
Euchrysops cnejus (F.)	Blue Butterfly	Lycaenidae	India }	
Helicoverpa armigera (Hub.)	American Bollworm	Noctuidae	Old World	Larvae eat leaves & pods
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India	Larvae eat leaves
Spodoptera exigua (Hbn.)	Lesser Armyworm	Noctuidae	India	Larvae eat leaves
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	India	Larvae defoliate
Plusia orichalcea F.	Pea Semi-looper	Noctuidae	India	Larvae eat leaves
Plusia signata F.	Semi-looper	Noctuidae	Malaysia	Larvae eat leaves
Diacrisia obliqua Wlk.	Tiger Moth	Arctiidae	India	Larvae defoliate
Phytomyza horticola Goureau	Pea Leaf Miner	Agromyzidae	Old World	Larvae mine leaves
Ophiomyia phaseoli (Tryon)	Bean Fly	Agromyzidae	India	Larvae bore stem
Tipula spp.	Leatherjackets	Tipulidae	Europe	Larvae eat roots
Anomala spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots
Epicauta spp.	Black Blister Beetles	Meloidae	Asia, USA, Canada	Adults eat flowers
Bruchus pisorum L.	Pea Pod Beetle	Bruchidae	Bangladesh, Europe, Canada	Attack ripe pods
Callosobruchus chinensis L.	Oriental Cowpea Bruchid	Bruchidae	Bangladesh	Attack ripe pods
Chaetocnema concinnipennis Baly	Flea Beetle	Chrysomelidae	Bangladesh	Adults hole leaves
Alcidodes spp.	Striped Weevils	Curculionidae	Bangladesh	Adults eat leaves
Sitona spp.	Pea & Bean Weevils	Curculionidae	Europe	Adults notch leaf margins
Tanymecus indicus Fst.	Surface Weevil	Curculionidae	India	Adults cut seedling stems
Hylastinus obscurus (Mar.)	Clover Root Borer	Scolytidae	USA	Larvae bore roots
Tetranychus spp.	Red Spider Mites	Tetranychidae	Cosmopolitan	Scarify foliage

PEACH (*Prunus persicae* – Rosaceae)

This is a tree native to China, which is grown commercially in temperate and sub-tropical areas. The more important centres of cultivation are S. USA, southern Europe, S. Africa, Australia, and Japan. The tree is small, rather short-lived, and susceptible to frost injury and low temperatures. The fruit has a soft velvety skin, a pitted compressed stone, is used mainly as a table fruit. Because of their delicate perishable nature, the fruits are difficult to transport and store, but they are the most popular fruit for canning, and large quantities are also dried. Nectarine is var. *nectarina* and clearly very closed allied to peach, but with a smaller, smooth fruit.

MAJOR PESTS

Myzus persicae (Sulz.)	Peach–Potato Aphid (Green Peach Aphid)	Aphididae	Cosmopolitan	Infest foliage
Quadraspidiotus perniciosus (Comst.)	San José Scale	Diaspididae	Pantropical	Encrust foliage
Cydia molesta (Busck.)	Oriental Fruit Moth	Tortricidae	Europe, E. Asia, Australia, N. & S. America	Larvae bore fruit
Cydia pomonella (L.)	Codling Moth	Tortricidae	Europe, S. Africa, China, Australia, NZ, N. & S. America	Larvae bore fruit
Ceratitis capitata (Wied.)	Mediterranean Fruit Fly	Tephritidae	Europe, Africa, Asia, C. & S. America	Larvae inside fruit
Ceratitis rosa Karsch	Natal Fruit Fly	Tephritidae	S. & E. Africa	Larvae inside fruit
Panonychus citri (McG.)	Citrus Red Spider Mite	Tetranychidae	S. Africa	Scarify foliage

MINOR PESTS

Aphis spiraecola Patch	Apple Aphid	Aphididae	Cosmopolitan	
Appelia schwartzi Borner	Peach Aphid	Aphididae	Europe	
Brachy caudus persicae (Pass.)	Black Peach Aphid	Aphididae	Europe	
Hyalopterus pruni Geoff.	Mealy Plum Aphid	Aphididae	Europe	
Hysteroneura setariae (Thomas)	Rusty Plum Aphid	Aphididae	Pantropical (esp. USA)	Infest foliage,
Pterochloroides persicae (Chol.)	Peach Aphid	Aphididae	Med. C. Asia	suck sap
Parthenolecanium corni (Bch.)	Plum Scale	Coccidae	Europe, W. Asia, Med.	
Parthenolecanium persicae (F.)	Peach Scale	Coccidae	Cosmopolitan	
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Almost cosmopolitan	
Drosicha mangiferae Green	Mango Giant Mealybug	Margarodidae	India	Encrust foliage
Pseudaulacaspis pentagona (Targ.)	White Peach Scale	Diaspididae	Cosmopolitan	Encrust twigs
Lygocoris pabulinus (L.)	Common Green Capsid	Miridae	Europe	Sap-sucker; toxic
Lygus oblineatus (Say)	Tarnished Plant Bug	Miridae	N. America	saliva
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	India, S.E. Asia	Larvae inside fruits
Dacus zonatus Saund.	Peach Fruit Fly	Tephritidae	India	Larvae inside fruits
Ceratitis cosyra (Wlk.)	Mango Fruit Fly	Tephritidae	Africa, Australia, C. & S. America	Larvae inside fruits
Pardalaspis quinaria Bez.	Rhodesian Fruit Fly	Tephritidae	S. & N.W. Africa	Larvae inside fruits
Anastrepha fraterculus (Wied.)	–	Tephritidae	C. & S. America	Larvae inside fruits
Rhagoletis completea Cress.	Walnut Husk Fly	Tephritidae	USA	Larvae inside fruits
Dichocrocis punctiferalis (Guen.)	Peach Moth	Pyralidae	Thailand, India	Larvae bore buds & fruits
Paramyelois transitella (Wlk.)	Navel Orange-worm	Pyralidae	USA (California)	Larvae bore fruits
Spilonota ocellana (D. & S.)	Eye-spotted Bud Moth	Tortricidae	Europe, Asia, N. America	Larvae bore buds
Anarsia lineatella Zell.	Peach Twig Borer	Gelechiidae	Europe, Asia, S. China, N. America	Larvae bore twigs
Conotrachelus nenuphar (Hbst.)	Plum Curculio	Curculionidae	USA	Larvae bore fruits
Tetranychus urticae (Koch)	Temperate Red Spider Mite	Tetranychidae	Europe	Scarify foliage
Panonychus ulmi (Koch)	Fruit Tree Red Spider Mite	Tetranychidae	Europe	Scarify foliage
Vasates cornutus Banks	Silver Mite	Eriophyidae	USA	Scarify foliage
Tarsonemus waitei Banks	–	Tarsonemidae	USA	Scarify foliage

PECAN (*Carya illinoensis* – Juglandaceae) (Hickory Nut)

Pecan is a native of the southeastern USA and Mexico. The nuts were originally harvested from wild trees but they have so increased in popularity that the trees are now being extensively cultivated in the southern States, particularly in Texas and Oklahoma, and with the development of new varieties the area of cultivation is spreading farther northwards. The trees start to bear nuts within four years of setting out, and paper-shelled varieties have now been developed. About half the annual crop is now marketed in the shell. Pecans have a higher fat content than any other vegetable product (over 70%). The nuts are used for dessert, and in icecream, cakes, candy, etc.

MAJOR PESTS

MINOR PESTS

Melanocallis caryaefoliae (Davis)	Black Pecan Aphid	Aphididae	USA	Infest foliage
Phylloxera notabilis Pergande	Pecan Leaf Phylloxera	Phylloxeridae	USA	Infest leaves
Clastoptera achatina Germ.	Pecan Spittlebug	Cercopidae	USA	Sap-sucker
Gretchena bolliana (Sling.)	Pecan Bud Borer	Tortricidae	USA	Larvae bore buds
Hemiberlesia lataniae	Armoured Scale	Diaspididae	Israel	Infest foliage
Retithrips syriacus	Thrips	Thripidae	Israel	Infest foliage
Paramyelois transitella (Wlk.)	Navel Orangeworm	Pyralidae	USA (California)	Larvae bore young fruits
Cossula magnifica (Streck.)	Pecan Carpenter-worm	Cossidae	USA	Larvae bore branches
Acrobasis juglandis (Le Baron)	Pecan Leaf Casebearer	Coleophoridae	USA	Larvae defoliate
Acrobasis caryae Grote	Pecan Nut Casebearer	Coleophoridae	USA	Larvae defoliate
Coleophora caryaefoliella Clemens	Pecan Cigar Casebearer	Coleophoridae	USA	Larvae defoliate
Curculio caryae (Horn)	Pecan Weevil	Curculionidae	USA	Larvae bore kernel
Tetranychus spp.	Red Spider Mites	Tetranychidae	USA	Scarify foliage
Aceria caryae Pergande	Pecan Leafroll Mite	Eriophyidae	USA	Distort young leaves

PEPPER (*Piper nigrum* – Piperaceae)

Black pepper is the dried unripe fruits (berries) of a weak vine, native to the Indo-Malaysian region, but now widely cultivated in the hot, humid eastern tropics. The plants are supported on posts or on living trees, and yield a crop after 2–3 years, reaching full bearing in seven years. White pepper comes from berries that are almost ripe, and is less pungent in nature.

MAJOR PESTS				
Lepidosaphes piperis G.	Pepper Scale	Diaspididae	India	Infest foliage
Dasynus piperis Chin.	Pepper Bug	Coreidae	Indonesia, Malaysia	Sap-sucker; toxic saliva
Longitarsus nigripennis Motsch.	Pepper Flea Beetle	Chrysomelidae	India	Larvae bore berries
Lophobaris piperis M.	Pepper Bark Weevil	Curculionidae	Indonesia, Malaysia	Larvae bore bark
MINOR PESTS				
Aleurocanthus piperis Mask.	Pepper Whitefly	Aleyrodidae	India	Infest foliage; sap-suckers
Amrasca devastans (Dist.)	Cotton Leafhopper	Cicadellidae	India, S.E. Asia	
Ferrisia virgata Ckll.	Striped Mealybug	Pseudococcidae	S.E. Asia, India	Encrust foliage
Saissetia coffeae Wlk.	Helmet Scale	Coccidae	S.E. Asia	Encrust foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	India	Encrust foliage
Pinnaspis spp.	Armoured Scales	Diaspididae	India	Encrust foliage
Disphinctus maesarum Kirk.	Capsid Bug	Miridae	India, Sri Lanka	Sap-sucker; toxic saliva
Pachypeltis sp.	Capsid Bug	Miridae	Indonesia	
Elasmognathus greeni Kby.	Lace Bug	Tingidae	Indonesia, Sri Lanka	Sap-sucker; toxic saliva; destroy flowers
Diplogomphus hewetti Dist.	Pepper-flower Lace Bug	Tingidae	Indonesia	
Gnorimoschema gudmannella Wals.	Pepper Flower-bud Moth	Gelechiidae	C. America	Larvae bore flower buds
Gynaikothrips karny Bagn.	Leaf-roller Thrips	Phlaeothripidae	India	Cause leaf galls
Gynaikothrips spp.	Thrips	Phlaeothripidae	India, Japan	Cause leaf galls
Thosea spp.	Stinging Caterpillars	Limacodidae	India, Indonesia, China	Larvae defoliate
Cricula trifenestrata Helf.	Hairy Mango Caterpillar	Saturniidae	India	Larvae defoliate
Laspeyresia hemidoxa Meyr.	Pepper Top Shoot Borer	Tortricidae	India, Indonesia	Larvae bore shoots
Cecidomyia malabarensis Felt	Pepper Gall Midge	Cecidomyiidae	India	Larvae bore berries
Aphthonomorpha collaris Baly	Pepper Flea Beetle	Chrysomelidae	Indonesia, China	Adults hole foliage & young fruit
Pagria costatipennis Jacoby	Flea Beetle	Chrysomelidae	India	Damage foliage
Neculla pollinaria Baly.	Flea Beetle	Chrysomelidae	India	Damage foliage
Eugnathus curvus Faust.	Pepper Weevil	Curculionidae	India	Damage foliage
Lophobaris serratipes pishll	Large Pepper Weevil	Curculionidae	Indonesia	Larvae bore damaged stems

PIGEON PEA (*Cajanus cajan* – Leguminosae) (= Cajan Pea; Red Gram; Dhal; Tur)

This crop originated either in Africa or India, but is now widely cultivated in warmer regions. The plant is an erect shrub, and both immature and ripe seeds are used for human and animal food. It is now being used as a forage crop and rivals alfalfa in importance, being drought-resistant and capable of growing in almost any type of soil. It is one of the most promising legumes at the present time. The main areas of production are India, W. Indies, E. Indies, Africa and S. America.

MAJOR PESTS

Helicoverpa armigera Hbn.	Old World Bollworm	Noctuidae	India, W. Indies	Larvae hole pods
Melanagromyza obtusa Mall.	Bean Pod Fly	Agromyzidae	India, S.E. Asia	Larvae mine leaves, bore pods & eat seeds

MINOR PESTS

Aphis craccivora Koch	Groundnut Aphid	Aphididae	India	Infest foliage
Coccus spp.	Soft Scales	Coccidae	India	Infest foliage
Margarodes spp.	'Mealybugs'	Margarodidae	India	Infest foliage
Coptosoma spp.	Stink Bugs	Pentatomidae	Malaysia, India	Sap-sucker; toxic saliva
Clavigralla spp.	Gram Pod Bugs	Coreidae	India }	Sap-suckers on pods & seeds
Riptortus spp.	Coreid Bugs	Coreidae	India }	
Stomopteryx subsecivella Zell.	Leaf Miner	Gracillariidae	India	Larvae mine leaves
Eucosma spp.	Leaf Rollers	Tortricidae	India	Larvae roll leaves
Elasmopalpus rubedinellus Zell.	Pod Borer	Pyralidae	W. Indies	Larvae bore pods
Etiella zinckenella Treit.	Pea Pod Borer	Pyralidae	India	Larvae bore pods
Ancylostomia stercorea (Zell.)	–	Pyralidae	W. Indies	Larvae eat pods
Catochrysops spp.	Blue Butterflies	Lycaenidae	India	Larvae bore pods
Amsacta spp.	Tiger Moths	Arctiidae	India, Malaysia	Larvae defoliate
Heliothis virescens (F.)	Tobacco Budworm	Noctuidae	W. Indies	Larvae bore pods
Dasychira mendosa Hbn.	Tussock Moth	Lymantriidae	Malaysia, India	Larvae defoliate
Megachile spp.	Leaf Cutter Bees	Megachilidae	India	Adults defoliate
Solenopsis geminata F.	Fire Ant	Formicidae	India	Attack workers
Mylabris pustulata Th.	Blister Beetle	Meloidae	India	Adults eat flowers
Callosobruchus chinensis (L.)	Cowpea Bruchid	Bruchidae	India	Attack ripe seeds
Sphenoptera perotetti G.	Stem Borer	Buprestidae	India	Larvae bore stems
Ceutorhynchus asperulus Fst.	Bud Weevil	Curculionidae	India	Larvae destroy bud
Eucolobes sp.	Weevil	Curculionidae	Malaysia	Damage foliage
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves

PINEAPPLE (*Ananas cosmosus* – Bromeliaceae)

The country of origin was S. America, but this crop is now grown widely throughout the tropics, and can be grown in heated greenhouses in temperate countries. It is grown most successfully in tropical lowlands, but requires a fertile soil, although it can survive a low rainfall; it can be grown successfully under irrigation. In habit it is a rosette plant with strong spiky leaves, about a metre in height, in appearance quite similar to small *Agave* plants. The fruit is a multiple organ formed from the coalescence of 100 or more individual flowers, with a very high sugar content, and is rich in vitamins A and C. The fruit is orange when ripe, with yellow flesh, and is eaten fresh as a table fruit, canned, or crushed for juice. It can be shipped unripe easily. Propagation is by slips, suckers and fruit crowns. The main production areas are Hawaii, Malaysia, Cuba, Brazil, Australia, S. Africa, and Kenya.

MAJOR PESTS				
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	India, S.E. Asia, Africa, C. & S. America	Infest leaf-bases & roots
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Infest leaves
Thrips tabaci Lind.	Onion Thrips	Thripidae	India	Scarify leaves; virus vector
Leucopholois irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots

MINOR PESTS				
Rhinotermes intermedius Br.	Termite	Rhinotermitidae	Australia	Damage plants
Acheta bimaculata Deggar	Two-spotted Cricket	Gryllidae	China	Damage plants
Planococcus citri Risso	Root Mealybug	Pseudococcidae	Pantropical	Infest roots
Aonidiella aurantii (Mask.)	California Red Scale	Diaspididae	Philippines	Infest leaves & fruit
Diaspis bromeliae (Kern.)	Pineapple Scale	Diaspididae	Malaysia	Infest leaves & fruit
Tmoleus echion L.	Pineapple Caterpillar	Lycaenidae	Hawaii, C. & S. America	Larvae bore fruit
Thecla basilides (Geyer)	Fruit-boring Caterpillar	Lycaenidae	S. America	Larvae bore fruit
Castnia licas (Drury)	Giant Moth Borer	Castniidae	Brazil	Larvae bore stem
Hoplothrips anansi Da C.L.	Pineapple Thrips	Thripidae	S. America	Infest shoots
Hercinothrips femoralis (Reut.)	Banded Greenhouse Thrips	Thripidae	Cosmopolitan	Infest foliage
Atherigona spp.	Fruit Maggots	Muscidae	India, Malaysia	Larvae bore fruit
Ahasverus advena (Waltl)	Foreign Grain Beetle	Cucujidae	Malaysia	Larvae damage fruit
Urophotus humeralis	Sap Beetle	Nitidulidae	Pantropical	Feed or fruits
Baris spp.	–	Curculionidae	S. America	Larvae mine stem
Strategus juguatha	Stem Borer	Scarabaeidae	S. America	Adult bores stem
Metamasius ritchei Bs.	Weevil Borer	Curculionidae	W. Indies	Larvae bore stem or fruit
Tarsonemus ananas Tryon	Pineapple Mite	Tarsonemidae	Australia	Damage shoot & young leaves

PISTACHIO (*Pistacia vera* – Anacardiaceae) (= Green Almond)

This is a small tree, native to western Asia and cultivated in the Mediterranean region for more than 4000 years. It is now grown in Iran, Afghanistan, and in California and other southern states of the USA. The fruit is a drupe; the seeds contain two large green cotyledons with a reddish covering. The 'nuts' are salted in brine while still in the slightly opened shell; they are highly prized for their flavour and colour, and are sold widely in cans or in mixed nuts, and as a flavouring in icecream and candy.

Other species of *Pistacia* yield a high-grade, and very expensive, resin called mastic. (See also Hammad & Mohamed, 1965.)

MAJOR PESTS

Recurvaria pistaciicola Danil	Pistachio Moth	Olethreutidae	Syria	Larvae web leaves & defoliate
Eurytoma sp.	Gall Wasp	Eurytomidae	Syria	Larvae gall kernel in young fruits
Hylesinus vestitus Muls-Rey	Shot-hole Borer	Scolytidae	Syria	Adults bore twigs & branches

MINOR PESTS

Agonoscena targionii (Litch.)	Psyllid	Psyllidae	Syria	Nymphs & adults suck sap
Idiocerus stali Fieb.	Leafhopper	Cicadellidae	Syria	Sap-sucker; infests foliage
Forda spp.	Woolly Aphids	Eriosomatidae	Near East	Leaf galls
Anapulvinaria pistaciae (Bod.)	Pistachio Brown Scale	Coccidae	Syria	Encrust foliage
Ceroplastes rusci (L.)	Fig Wax Scale	Coccidae	Med.	Encrust foliage
Salicicola pistaciae Lind.	Pistachio Scale	Coccidae	Syria	Encrust foliage
Melanaspis inopinatus Leon.	Armoured Scale	Diaspididae	Syria	Encrust foliage
Lygaeus pandurus Scop.	Lygaeid Bug	Lygaeidae	India	Sap-sucker; toxic saliva
Retithrips syriacus Mayet	Black Vine Thrips	Thripidae	Syria, Israel	Infest foliage
Paramyelois transitella (Wlk.)	Navel Orange-worm	Pyralidae	USA (California)	Larvae bore young fruits
Pachypasa otus (Dru.)	–	Lasiocampidae	Syria	Larvae defoliate
Capnodis spp. (6)	Jewel Beetles	Buprestidae	Syria	Larvae bore branches & trunk, sometimes roots
Eriophyes pistaciae Nal.	Pistachio Bud Mite	Eriophyidae	Near East	Leaf deformation & 'brooming'
Eriophyes stephanii Nal.	Pistachio Leaf-edge Roll Mite	Eriophyidae	Near East	Leaf edges rolled

PLUM (*Prunus domestica* – Rosaceae)

The plums of commerce come from three main sources; the European plums, native American species, and Japanese species. However, the bulk of fruit comes from the European Plum which is now very widely cultivated throughout the temperate parts of the world. It has been cultivated for over 2000 years, and was taken to America by the colonists. It is a large tree, 10–16 m in height, with variously coloured fruits; over 900 varieties are cultivated, although certain varieties are only used for cooking or for drying as prunes. The fruit is soft and fleshy, the stone smooth and flattened.

MAJOR PESTS

Brachycaudus helichrysi (Kalt.)	Plum Aphid	Aphididae	Europe, Australia	Infest foliage
Phorodon humuli (Schrank)	Damson Aphid	Aphididae	Europe, USA, Canada	Infest foliage
Hyalopterus pruni (Geoff.)	Mealy Aphid	Aphididae	Europe	Infest foliage
Parthenolecanium corni (Bch.)	Plum Scale	Coccidae	Europe	Infest foliage
Cydia funebrana (Treits.)	Red Plum Maggot	Tortricidae	Europe, Asia	Larvae bore fruits
Operophtera brumata (L.)	Winter Moth	Geometridae	Europe	Larvae defoliate
Caliroa cerasi (L.)	Pear Slug Sawfly	Tenthredinidae	Cosmopolitan	Larvae skeletonize leaves
Hoplocampa flava (L.)	Plum Sawfly	Tenthredinidae	Europe	Larvae defoliate
Panonychus ulmi (Koch)	Fruit Tree Red Spider Mite	Tetranychidae	Cosmopolitan	Scarify leaves

MINOR PESTS

Macropsis trimaculata (Fitch)	Plum Leafhopper	Cicadellidae	USA	Infest foliage
Hysteroneura setariae (Th.)	Rusty Plum Aphid	Aphididae	Cosmopolitan	Infest foliage
Lygocoris pabulinus (L.)	Green Capsid	Miridae	Europe	Sap-sucker
Taeniothrips inconsequens (Uzel)	Pear Thrips	Thripidae	Europe	Infest foliage
Hoplocampa minuta (Christ)	Plum Sawfly	Tenthredinidae	Europe	Larvae defoliate
Neurotoma inconspicua (Nort.)	Plum Sawfly	Tenthredinidae	USA	Larvae defoliate
Vespula/Vespa spp.	Common Wasps	Vespidae	Cosmopolitan	Adults puncture ripe fruits
Spilonota ocellana (D. & S.)	Bud Moth	Tortricidae	Cosmopolitan	Larvae bore buds
Hedya pruniana (Hubn.)	Plum Tortrix	Tortricidae	Europe	Larvae bore shoots
Paramyelois transitella (Wlk.)	Orangeworm	Pyralidae	USA	Larvae bore fruits
Antheraea polyphemus	Emperor Moth	Saturniidae	USA	Larvae defoliate
Euproctis spp.	Browntail Moths	Lymantriidae	Cosmopolitan	Larvae defoliate
Anthonomus scutellaris Le Conte	Plum Gouger	Curculionidae	USA	Larvae bore fruits
Conotrachelus nenuphar Herbst	Plum Weevil	Curculionidae	USA	Larvae bore fruits
Otiorhynchus cribricollis Gylh.	Apple Weevil	Curculionidae	Med., W. USA, Australia	Larvae eat roots adults eat leaves
Scolytes mali Bht.	Large Fruit Bark Beetle	Scolytidae	Europe	Adults bore under bark
Scolytes rugulosus (Muller)	Fruit Bark Beetle	Scolytidae	Eurasia, N. & S. America	Adults bore under bark
Eriophyes pyri (Pgst.)	Blister Mite	Eriophyidae	Cosmopolitan	Blister leaves
Vasates fockeui (N. & T.)	Plum Mite	Eriophyidae	Canada, USA	Distort leaves

POMEGRANATE (*Punica granatum* – Punicaceae)

A native of Iran, this plant has been cultivated in the Mediterranean region for centuries, and was early taken to India, S.E. Asia and China. It is now grown in most parts of the tropics and sub-tropics where the climate is not too humid. The best quality fruits are produced in areas with hot dry summers and cool winters. The plant is a bush or small tree, 2–4 m in height, deciduous in cooler regions, and the fruit is a round brown berry, 5–12 cm in diameter, containing many seeds embedded in a pink juicy pulp. The acid pulp is the edible part of the fruit, and may be eaten as a dessert fruit, as a salad, or in beverages. The roots, rinds, and seeds are used medicinally. Propagation is usually by cuttings. Areas of some commercial production are California, Israel, Arizona, and New Mexico. (See also Butani, 1976*a*.)

MAJOR PESTS				
Indarbela spp.	Bark Moths	Metarbelidae	India	Larvae eat bark
Virachola isocrates (F.)	Pomegranate Butterfly	Lycaenidae	India, Israel	Larvae bore fruits

MINOR PESTS				
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	Pantropical	Infest foliage; suck sap
Siphoninus sp.	Whitefly	Aleyrodidae	India, Israel	
Aphis punicae	Aphid	Aphididae	India	
Drosicha mangiferae (Green)	Giant Mealybug	Margarodidae	India	
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	
Planococcus lilacinus (Ckll.)	Cocoa Mealybug	Pseudococcidae	India, Israel	
Parlatoria oleae (Col.)	Olive Scale	Diaspididae	India	Infest twigs; suck sap
Aspidiotus rossi (Mask.)	Pomegranate Scale	Diaspididae	India	Infest twigs
Retithrips syriacus (Mayet)	Thrips	Thripidae	India	Infest foliage
Zeuzera coffeae Neitn.	Red Coffee Borer	Cossidae	India	Larvae bore stems
Clania crameri Westw.	Bagworm	Psychidae	India	Larvae defoliate
Deudorix epijarbas (Moore)	Pomegranate Borer	Pyralidae	India	Larvae bore fruits
Dichocrocis punctiferalis (Guen.)	Castor Capsule Borer	Pyralidae	India	Larvae bore fruits
Latoia lepida (Cram.)	Blue-striped Nettlegrub	Limacodidae	India	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantriidae	India	Larvae defoliate
Othreis fullonia (L.)	Fruit-piercing Moth	Noctuidae	India	Adults pierce ripe fruits
Dacus spp.	Fruit Flies	Tephritidae	India	Larvae inside fruits
Anomala spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves
Olenecamptus bilobus F.	Stem Borer	Cerambycidae	India	Larvae bore stems
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves

POTATO (*Solanum tuberosum* – Solanaceae) (= Irish Potato)

Wild species are found from S. USA to S. Chile, with the centre of diversity in the Andes between 10°N and 20°N at altitudes above 2000 m. They spread slowly, to the Philippines and India in the 17th century, later to Europe, Japan, Java, and E. Africa. It is essentially a temperate crop, and is grown in the tropics only at high altitudes, using shorter-day cultivars. The usual cultivars are long-day forms. Optimum temperatures for tuber development are about 16°C (not above 27°C), and the crop can be grown successfully under irrigation. It is a herbaceous branched annual 0.3–1 m in height; the swollen stem tubers contain about 2% protein, 17% starch. It is grown more universally than any other crop. Propagation is by tubers or seed.

MAJOR PESTS				
Aulacorthum solani (Kalt.)	Potato Aphid	Aphididae	Cosmopolitan	Infest foliage; suck sap; virus vectors
Myzus persicae (Sulz.)	Peach–Potato Aphid	Aphididae	Cosmopolitan	
Phthorimaea operculella (Zeller)	Potato Tuber Moth	Gelechiidae	Pantropical	Larvae bore stems & tubers
Epilachna spp.	Epilachna Beetles	Coccinellidae	Africa, China, India	Adults & larvae eat leaves
Leptinotarsa decemlineata (Say)	Colorado Beetle	Chrysomelidae	Europe (not UK), N. & C. America	Adults & larvae eat leaves
Diabrotica spp.	Rootworms	Chrysomelidae	N.C. & S. America	Ads hole leaves larvae eat roots
Agriotes spp.	Wireworms	Elateridae	Europe, Asia, USA	Larvae in soil eat roots & bore tubers
MINOR PESTS				
Amrasca devastans (Dist.)	Leafhopper	Cicadellidae	India, S.E. Asia	Infest foliage; stunt plants; virus vectors
Empoasca spp.	Green (Potato) Leafhoppers	Cicadellidae	Europe, Africa, Asia, Americas	
Cicadella aurata (L.)	Leafhopper	Cicadellidae	Europe	
Typhlocyba jucunda Herr.-Schafff.	Leafhopper	Cicadellidae	Europe	
Bemisia spp.	Whiteflies	Aleyrodidae	Pantropical	
Macrosiphum euphorbiae (Thos.)	Potato Aphid	Aphididae	Cosmopolitan	Infest foliage; suck sap; virus vectors
Rhopalosiphoninus latysiphon (Davids.)	Bulb & Potato Aphid	Aphididae	Europe, India	
Aphis nasturtii (Borner)	Buckthorn – Potato Aphid	Aphididae	Europe, India	
Planococcus citri (Risso)	Root Mealybug	Pseudococcidae	Pantropical	Infest roots or foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Cosmopolitan	Infest foliage
Lygocoris pabulinus (L.)	Green Capsid	Miridae	Europe	
Calocoris norvegicus (Gmel.)	Potato Capsid	Miridae	Europe, Australia	
Lygus rugulipennis Popp.	Tarnished Plant Bug	Miridae	Europe	Sap-sucker; toxic saliva
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	
Bagrada spp.	Harlequin Bugs	Pentatomidae	Africa, Asia	
Hepialus spp.	Swift Moths	Hepialidae	Europe	Larvae in soil eat roots and bore tubers
Scrobipalpopsis solanivora	Potato Tuber Moth	Gelechiidae	C. America	Larvae; leaves tubers
Leucinodes orbonalis Guen.	Eggplant Fruit Borer	Pyralidae	Africa, S. Asia	Larvae eat foliage
Noctua pronuba (L.)	Large Yellow Underwing	Noctuidae	Europe	
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	Cosmopolitan	Larvae are cutworms; live in soil and eat into tubers
Agrotis segetum (D. & S.)	Common Cutworm	Noctuidae	Cosmopolitan in Old World	
Agrotis exclamationis (L.)	Heart & Dart Moth	Noctuidae	Europe	
Hydraecia micacea (Esp.)	Rosy Rustic Moth	Noctuidae	Europe, USA	Larvae bore stems

(continued)

Helicoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	India	Larvae defoliate
Acherontia atropos (L.)	Death's Head Hawk Moth	Sphingidae	Europe, Africa, Asia	Larvae defoliate
Liriomyza huidobrensis	Potato Leaf mine	Agromyzidae	S. America	Larvae mine leaves
Tipula spp.	Leatherjackets	Tipulidae	Europe	Larvae in soil eat roots
Nephrotoma maculata Meig.	Spotted Cranefly	Tipulidae	Europe, Asia Canada	
Frankliniella spp.	Thrips	Thripidae	Cosmopolitan	Scarify foliage
Melolontha spp.	Cockchafers	Scarabaeidae	Europe	Larvae are white grubs or chafers; live in soil and eat into tubers
Phyllopertha horticola (L.)	Garden Chafer	Scarabaeidae	Europe	
Phyllophega spp.	White Grubs	Scarabaeidae	N. S. America	
Amphimallon solstitialis (L.)	Summer Chafer	Scarabaeidae	Europe	
Cetonia aurata (L.)	Rose Chafer	Scarabaeidae	Europe	
Serica spp.	Brown Chafers	Scarabaeidae	Europe, Asia	
Aspidomorpha spp.	Tortoise Beetles	Chrysomelidae	Africa	Adults & larvae eat leaves
Psylliodes affinis (Payk.)	Potato Flea Beetle	Chrysomelidae	Europe	Adults hole leaves, larvae eat tubers
Epitrix spp.	Flea Beetles	Chrysomelidae	Canada, USA, C.S. America	
Drasterius spp.	Wireworms	Elateridae	Asia	Larvae in soil eat roots and bore tubers
Limonius spp.	Wireworms	Elateridae	USA, Canada	
Hypolithus spp.	Wireworms	Elateridae	USA, Canada	
Epicauta spp.	Striped Blister Beetles	Meloidae	Africa, USA, S. America	Adults destroy leaves
Premnotrypes spp.	Andes Weevils	Curculionidae	S. America	Adults eat leaves; larvae bore tubers
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Cosmopolitan	Scarify foliage
Tetrarychus spp	Red Spider Mites	Tetranchidae	Cosmopolitan	Scarify & web foliage

PYRETHRUM (*Chrysanthemum cinerariifolium* – Compositae)

The origin of this plant is the Dalmatian coast of Yugoslavia; it was introduced into Japan in 1881, and to Kenya in 1929. The main production areas are Kenya, Uganda, Tanzania, New Guinea, Ecuador, Brazil, Japan, China, and India. It is a small tufted perennial herb, about 0.5 m in height, which thrives in areas of moderate rainfall (100–160 cm); in the tropics successful cultivation only occurs at high altitudes (e.g. 2000–3000 m in Kenya); chilling is required to initiate flower buds. The flowers are typical of composites, white with yellow centres. The dried flower heads contain pyrethrins (1.0–1.3%) which are very useful insecticides because of their effective 'knockdown' properties; 90% of the pyrethrins are in the ovary and the developing achenes. This crop is to some extent losing its importance with the recent successful development of synthetic pyrethrins, and pyrethroids.

MAJOR PESTS

Thrips nigropilosus Uzel	Pyrethrum Thrips	Thripidae	Europe, Africa, Canada, USA	Infest foliage & scarify

MINOR PESTS

Myzus persicae (Sulz.)	Green Peach Aphid	Aphididae	Cosmopolitan	Infest foliage
Brachycaudus helichrysi (Kalt.)	Leaf-curling Plum Aphid	Aphididae	Cosmopolitan	Infest foliage
Nysius sp.	Lygus Bug	Lygaeidae	E. Africa	Sap-sucker; toxic saliva
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Infest and damage flowers
Haplothrips gowdeyi (Frankl.)	–	Thripidae	Africa, S. America	Scarify foliage
Tetranychus ludeni (Zacher)	Red Spider Mite	Tetranychidae	Widespread	Scarify foliage

QUINCE (*Cydonia oblonga* – Rosaceae)

A small tree from 2–5 m in height, cultivated since ancient times but apparently little changed during cultivation; wild trees may be found in western Asia. It has a bushy habit with many branches. The leaves are woolly as are the young fruit. The flower is an attractive pink colour, and the large oblong fruit has golden-yellow flesh that is hard and rather unpalatable; it is used mainly to make jelly and marmalade, and is sometimes canned. The main areas of commercial production are the southern states of the USA and Israel. In Europe and Asia it is grown either for local consumption or as an ornamental shrub. It is not really a tropical species as it is usually grown in warm temperate or sub-tropical areas.

MAJOR PESTS

Cydia molesta (Busck)	Oriental Fruit Moth	Tortricidae	China, Japan, N. America	Larvae bore in fruits
Cydia pomonella (L.)	Codling Moth	Tortricidae	Europe, N. America	Larvae bore in fruits

MINOR PESTS

Eriosoma lanigerum (Hsm.)	Woolly Apple Aphid	Pemphigidae	Cosmopolitan	Encrust twigs
Ruguloscolytus amygdali	Bark Beetle	Scolytidae	Israel	Adults bore bark
Aphis pomi	Apple Aphid	Aphididae	Israel	Infest foliage, suck sap
Myzus petsiva	Green Peach Aphid	Aphididae	Israel	
Aleurocanthus woglumi Ashby	Citrus Blackfly	Aleyrodidae	India	Encrust foliage
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Widespread	Infest foliage
Eulecanium corylii L.	Soft Scale	Coccidae	India	Encrust foliage
Parthenolecanium persicae (F.)	Peach Scale	Coccidae	Cosmopolitan	Infest foliage
Coccus hesperidum	Soft Brown Scale	Coccidae	Israel	
Parlatoria oleae	Olive Scale	Coccidae	Israel	Infest foliage; suck sap
Planococcus citri	Citrus Mealybug	Pseudococcidae	Israel	Suck sap; toxic saliva
Stephanites pyri	Peak LaceBug	Tingidae	Israel	
Oxycatenus hyaliapennis	Seed Bug	Hygaeidae	Israel	
Cacaecia sarcostega Meyr.	Fruit Tree Tortrix	Tortricidae	India	Larvae damage fruits
Spilonota ocellana (D. & S.)	Eye-spotted Bud Moth	Tortricidae	India, Europe, Asia, N. America	Larvae bore buds
Zeuzera spp.	Leopard Moths	Cossidae	India, Europe	Larvae bore branches
Euproctis fraterna (Moore)	Tussock Moth	Lymantriidae	India	Larvae defoliate
Dacus dorsalis Hend.	Oriental Fruit Fly	Tephritidae	India	Larvae inside fruits
Aeolesthes sarta Solsky	Longhorn Beetle	Cerambycidae	India	Larvae bore trunk & branches
Conotrachelus nenuphar (Herbst.)	Plum Weevil (Curculio)	Curculionidae	USA	Larvae bore in fruits

RAMBUTAN (*Nephelium lappaceum* – Sapindaceae)

An evergreen bushy tree, up to 20 m tall, dioecious, native to the lowlands of Malaysia where it is widely cultivated. For reasons not known it is seldom successfully grown away from the indigenous area. The fruits are red-coloured, softly spiky, and borne in clusters; in good cultivars the edible aril is sweet, juicy and delicious, and is highly esteemed locally.

MAJOR PESTS

Tessaratoma papillosa (Dru.)	Litchi Stink Bug	Pentatomidae	Malaysia, Philippines	Adults & nymphs suck sap; toxic saliva
Porthesia scintillans Wlk.	Tussock Moth	Lymantriidae	Malaysia	Larvae defoliate

MINOR PESTS

Planococcus lilacinus (Ckll.)	Mealybug	Pseudococcidae	Philippines	Encrust leaves
Thalassodes depulsata Wlk.	Looper Caterpillar	Geometridae	Malaysia	Larvae defoliate
Acrocercops cramerella Sn.	Cocoa Pod Borer	Gracillariidae	Philippines	Larvae bore fruit
Pteroma plagiophleps Hmps.	Bagworm	Psychidae	Malaysia	Larvae defoliate
Stauropus alternus (Wlk.)	–	Notodontidae	Philippines, SE Asia	Larvae defoliate
Tarsolepis sommeri Hbn.	–	Notodontidae	Indonesia	Gregarious larvae eat foliage & defoliate
Dudusa nobilis Wlk.	–	Notodontidae	SE Asia, Indonesia, S. China	Gregarious larvae eat foliage & defoliate
Helina propinqua Stein.	–	Anthomyiidae	Malaysia	Larvae bore fruit
Adoretus compressus Weber.	Flower Beetle	Scarabaeidae	Malaysia	Adults damage fruit
Niphonoclea spp.	Twig Borers	Cerambycidae	Philippines	Larvae bore twigs
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	Thailand	Adults eat leaves

RICE (*Oryza sativa* – Gramineae)

Rice probably originated in China, but spread very early to India, and is now grown extensively throughout Asia, and is rapidly increasing in Africa, S. America, USA, Australia and southern Europe. Approximately 10% of the world rice-growing area is 'hill' rice which is grown dry like an ordinary cereal. 'Swamp' or 'padi' rice is grown in shallow standing water: either impounded rain water or irrigation water, some varieties can grow in river waters with floating foliage in the deltas of S.E. Asia. Many varieties are cultivated for different culinary purposes or to meet different requirements of cultivation; long grain and short grain rice have quite different cooking qualities. The most important production areas for export purposes are Thailand, Burma, India, China, and the USA; in most other countries the crop is largely for home consumption. Several plant breeding projects are in progress for selection of pest and disease resistance, the largest of which is at IRRI, Philippines. (See also Grist & Lever, 1969.)

MAJOR PESTS				
Homorocoryphus nitidulus Wlk.	Edible Grasshopper	Tettigoniidae	E. Africa	Defoliate
Oxya chinensis (Thunb.)	Small Rice Grasshopper	Acrididae	S.E. Asia, India, China	Defoliate
Nephotettix nigropictus (Stal)	Green Rice Leafhopper	Cicadellidae	India, S.E. Asia, China, Japan	Sap-sucker; virus vector
Nephotettix virescens (Dist.)	Green Rice Leafhopper	Cicadellidae	India, S.E. Asia, China	Sap-sucker; virus vector
Recilia dorsalis (Mot.)	Zig-zag Rice Leafhopper	Cicadellidae	India, S.E. Asia, China, Japan	Sap-sucker; virus vector
Laodelphax striatella (Fall.)	Small Brown Planthopper	Delphacidae	Philippines, Japan, Korea, Europe	Sap-sucker; virus vector; cause Hopperburn
Sogatella furcifera (Horv.)	White-backed Planthopper	Delphacidae	India, S.E. Asia, Korea, Japan	Sap-sucker; virus vector
Nilaparvata lugens (Stal)	Brown Rice Planthopper	Delphacidae	S.E. Asia	Sap-sucker; virus vector
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	S.E. Asia, Africa	Sap-sucker; toxic saliva
Leptocorisa acuta (Thnb.)	Asian Rice Bug	Coreidae	India, S.E. Asia, China, Japan, Australia	Sap-sucker; toxic saliva
Stenocoris southwoodi Ahmad	African Rice Bug	Coreidae	Africa	Sap-sucker; toxic saliva
Scotinophara coarctata (F.)	Black Rice Bug	Pentatomidae	India, S.E. Asia	Sap-sucker; toxic saliva
Diploxys fallax Stal	Rice Shield Bug	Pentatomidae	Africa	
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	Sap-sucker; toxic saliva
Oebalus pugnax (F.)	Rice Stink Bug	Pentatomidae	USA, Dominican Rep.	
Baliothrips biformis (Bag.)	Rice Thrips	Thripidae	India, S.E. Asia, Japan	Withered leaves
Chilo partellus (Swinhoe)	Spotted Stalk Borer	Pyralidae	India, Thailand, E. Africa	Larvae bore stalks
Chilo polychrysus (Meyr.)	Dark-headed Rice Borer	Pyralidae	E. Pakistan, India, S.E. Asia	Larvae bore stalks
Chilo suppressalis (Wlk.)	Striped Rice Borer	Pyralidae	India, S.E. Asia, China, Japan, Australia, Spain	Larvae bore stalks
Maliarpha separatella Rag.	White Rice Borer	Pyralidae	Burma, China, Africa	Larvae bore stalks
Nymphula depunctalis (Gn.)	Rice Caseworm	Pyralidae	India, S.E. Asia, Australia	Larvae eat leaves; make leaf cases
Cnaphalocrocis medinalis (Guen.)	Rice Leaf Folder	Pyralidae	India, S.E. Asia, Korea	Larvae fold leaves
Tryporyza incertulus (Wlk.)	Yellow Rice Borer	Pyralidae	India, S.E. Asia	Larvae bore stalks
Tryporyza innotata (Wlk.)	White Rice Borer	Pyralidae	India, S.E. Asia	Larvae bore stalks
Scirpophaga spp.	Small Rice Borers	Pyralidae	S.E. Asia	Larvae bore stalks
Telicota augias (L.)	Rice Skipper	Hesperiidae	Java, Philippines, Malaysia India	Larvae fold leaves
Mythimna unipuncta (Haw.)	Rice Armyworm	Noctuidae	Europe, W. & E. Africa, USA, C. & S. America	Larvae defoliate
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	India, S.E. Asia, Australasia	Larvae cut stems
Mythimna loreyi (Dup.)	Rice Armyworm	Noctuidae	S.E. Asia, Australasia	Larvae defoliate
Sesamia calamistis Hmps.	Pink Stalk Borer	Noctuidae	Africa	Larvae bore stems
Sesamia inferens (Wlk.)	Pink Borer	Noctuidae	India, S.E. Asia, China, Japan	Larvae bore stalks
Spodoptera exempta (Wlk.)	African Armyworm	Noctuidae	S.E. Asia, Africa	Larvae defoliate
Spodoptera exigua (Hb.)	Lesser Armyworm	Noctuidae	S.E. Asia, Africa, Europe, Australia, USA	Larvae defoliate
Spodoptera mauritia (Boisd.)	Rice Armyworm	Noctuidae	India, S.E. Asia, Africa, USA, Australia	Larvae defoliate

(continued)

MAJOR PESTS

Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India, S.E. Asia, Australasia	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa, Near East	Larvae defoliate
Spodoptera pecten (Guen.)	–	Noctuidae	Malaysia	Larvae defoliate
Orseolia oryzae (W-M)	Asian Rice Gall Midge	Cecidomyiidae	India, S.E. Asia }	Larvae gall stems
Orseolia Zyzivora H & G	African Rice Gall Midge	Cecidomyiidae	Africa }	
Atherigona oryzae Mall.	Rice Shoot Fly	Muscidae	India, S.E. Asia, Japan	Larvae destroy shoots
Diopsis spp.	Stalk-eyed Flies	Diopsidae	Africa	Larvae bore shoots
Hydrellia griseola Fall.	Rice Whorl Maggot	Ephydridae	Europe, N. Africa, S.E. Asia, Japan, USA, S. America	Larvae mine leaves
Dicladispa armigera (Ol.)	Paddy Hispid	Chrysomelidae	India, S.E. Asia, China	Larvae mine leaves
Trichispa serica (Gn.)	Rice Hispid	Chrysomelidae	Africa	Larvae mine leaves
Oulema oryzae Kuw.	Brown Leaf Beetle	Chrysomelidae	China, Japan	Adults strip, larvae eat leaves
Colaspis brunnea (F.)	Grape Colaspis	Chrysomelidae	S. USA	Larvae eat roots
Sitophilus oryzae (L.)	Rice Weevil	Curculionidae	S.E. Asia, China	Attack ripe seeds
Lissorhoptrus oryzophilus Kusch.	Rice Water Weevil	Curculionidae	USA, Japan	Larvae eat roots, adults leaves
Graphognathus spp.	White-fringed Weevils	Curculionidae	Australia, S. USA, S. America	Larvae eat roots

MINOR PESTS

Patanga succincta (L.)	Bombay Locust	Acrididae	India, S.E. Asia	Defoliate
Gastrimargus spp.	Grasshoppers	Acrididae	S.E. Asia, Africa	Defoliate
Oxya spp.	Small Rice Grasshoppers	Acrididae	India, S.E. Asia, China	Defoliate
Hieroglyphus banian (F.)	Large Rice Grasshopper	Acrididae	India, Indonesia, Thailand	Defoliate
Zonocerus spp.	Variegated Grasshoppers	Acrididae	E. & W. Africa	Defoliate
Locusta migratoria sspp.	Locusts	Acrididae	Africa, Asia	Defoliate
Gryllotalpa africana Pal.	Mole Cricket	Gryllotalpidae	Cosmopolitan	Damage roots
Balclutha viridis (Mat.)	Green-splashed Leafhopper	Cicadellidae	Thailand, Laos	Sap-sucker
Nephotettix spp.	Rice Green Leafhoppers	Cicadellidae	India, S.E. Asia, China }	
Cicadella spectra (Dist.)	White Jassid	Cicadellidae	Africa, India, S.E. Asia }	Sap-suckers; virus vectors
Sogatodes spp.	Rice Planthoppers	Delphacidae	S. USA, C. America }	
Rhopalosiphum padi (L.)	Rice Aphid	Aphididae	S.E. Asia	Infest foliage
Rhopalosiphum rufiabdominalis (Sasaki)	Rice Root Aphid	Aphididae	S.E. Asia	Infest roots
Hystoneura setariae (Thon.)	Rusty Plum Aphid	Aphididae	S.E. Asia }	
Rhopalosiphum maidis (Fitch)	Corn Aphid	Aphididae	Cosmopolitan }	Infest foliage; sap-suckers
Nisia atrovenosa Leth.	Rice Leafhopper	Meenoplüdae	India, China, Japan, Africa, Australia }	
Pyrilla petpusilla Wlk.	Sugarcane Leafhopper	Lophopidae	India, S.E. Asia	Infest foliage
Brevennia rehi (Ldgr.)	Rice Mealybug	Pseudococcidae	India, Thailand, Java, USA	Infest foliage
Saccharicoccus sacchari (Ckll.)	Sugarcane Mealybug	Pseudococcidae	Pantropical	Infest leaf bases
Dysmicocus spp.	Pineapple Mealybug	Pseudococcidae	Pantropical	Infest leaf bases
Leptocorisa spp.	Rice Bugs	Coreidae	S.E. Asia	Sap-suckers; toxic saliva

(continued)

MINOR PESTS				
Blissus gibbus F.	Lygaeid Bug	Lygaeidae	Laos	Sap-sucker; toxic saliva
Megarhamphus hastatus	Shield Bug	Pentatomidae	China	
Oebalus poecilus	Rice Stink Bug	Pentatomidae	Indonesia	
Haplothrips aculentus (F.)	Thrips	Phaleothripidae	Palaearctic	Infest foliage
Diatraea saccharalis (F.)	Sugarcane Borer	Pyralidae	N. & S. America	Larvae bore stems
Chilo auricilius Dudgeon	Gold-fringed Borer	Pyralidae	Thailand	Larvae bore stalks
Chilo infuscatellus Sn.	–	Pyralidae	India, S.E. Asia	Larvae bore stalks
Chilo spp.	Stem Borers	Pyralidae	Africa, Asia, USA	Larvae bore stems
Maruca testulalis (Geyer)	Mung Moth	Pyralidae	Pantropical	Larvae eat panicle
Tryporyza nivella (F.)	White Tip Borer	Pyralidae	Thailand	Larvae bore top of stems
Nymphula spp.	Rice Caseworms	Pyralidae	Japan, Italy Hungary	Larvae cut cases & eat leaves
Marasmia trapezalis (Gn.)	Maize Webworm	Pyralidae	Pantropical	Larvae web panicle
Eldana saccharina Wlk.	Sugarcane Stalk Borer	Pyralidae	Africa	Larvae bore stems
Rupela albinella (Cram.)	South American White Borer	Pyralidae	N. & S. America	Larvae bore stems
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	Cosmopolitan	Larvae cutworms
Remigia repanda (F.)	Guinea Grass Moth	Noctuidae	C. & S. America	Larvae defoliate
Sesamia spp.	Stem Borers	Noctuidae	Africa, Asia	Larvae bore stems
Spodoptera spp.	Armyworms	Noctuidae	Pantropical	Larvae defoliate
Sitotroga cerealella (Ol.)	Angoumois Grain Moth	Gelechiidae	Indo-China	Larvae infest panicle
Parnara guttata B. & C.	Rice Skipper	Hesperiidae	India, Indonesia, China, Japan	Larvae fold leaves
Pelopidas mathias (F.)	Rice Skipper	Hesperiidae	India, S.E. Asia, China, Africa	Larvae fold leaves
Ampittia dioscorides (F.)	Small Rice Skipper	Hesperiidae	India, Malaysia, S. China	Larvae fold leaves
Melanitis leda (L.)	Brown Butterfly	Nymphalidae	India, Philippines, Thailand	Larvae eat leaves
Chironomous spp.	Bloodworms	Chironomidae	Widespread	Larvae damage seedlings
Hydrellia spp.	Leaf Maggots	Ephydridae	Europe, Japan, S.E. Asia, USA	Larvae mine leaves
Notiphila spp.	Rice Root Maggots	Ephydridae	SE Asia, Japan	Larvae bore root & stems
Atherigona spp.	Shoot Flies	Muscidae	India, S.E. Asia, Japan	Larvae destroy apical shoot
Chlorops oryzae (Mats.)	Stem Maggot	Chloropidae	Japan	Larvae gall shoot
Heteronychus spp.	Cereal Beetles	Scarabaeidae	Africa, Australia	Adults bite stems; larvae eat roots
Lepidiota spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae eat roots
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae eat roots
Monolepta sp.	Corn Silk Beetle	Chrysomelidae	Philippines	Adults eat flowers
Echinocnemus oryzae (Marshall)	Rice Root Weevil	Curculionidae	India	Larvae eat roots under water
Several species	Rice Birds	Ploceidae	S.E. Asia; China	Eat ripening grains

ROSE APPLE (*Eugenia jambos* – Myrtaceae) (= *Syzygium jambos*)

This has long been cultivated in the Indo-Malaysian region for its reddish, rose-scented fruits which may be eaten fresh or made into preserves, and is now grown widely throughout the tropics, including Florida in the USA. The tree is evergreen, with lanceolate leaves and characteristic multistaminate flowers and grows to a height of 10 m.

MAJOR PESTS

MINOR PESTS

Megatrioza vitiensis (Kirk.)	Leaf Gall Psyllid	Psyllidae	India, Malaysia, S. China	Nymphs make leaf-pits
Trioza jambolanae C.	Leaf Gall Psyllid	Psyllidae	India	Nymphs make leaf-pits
Dialeurodes eugeniae Mask.	Rose Apple Whitefly	Aleyrodidae	India; S.E. Asia	Infest foliage
Dialeurodes vulgaris Singh	Whitefly	Aleyrodidae	India	Infest foliage
Aleurocanthus rugosa Singh	Blackfly	Aleyrodidae	India	Infest foliage
Chloropulvinaria psidii Mask.	Guava Scale	Coccidae	India	Infest foliage
Aonidiella orientalis (Newst.)	Oriental Scale	Diaspididae	India; S.E. Asia	Encrust twigs
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	India	Encrust twigs
Thrips florum Sch.	Flower Thrips	Thripidae	India	Infest flowers
Teuchothrips eugeniae S. & A.	Rose Apple Thrips	Thripidae	India; S.E. Asia	Infest leaves
Mallothrips indicus R.	Leaf Thrips	Thripidae	India	Infest leaves
Acrocercops spp.	Leaf Miners	Gracillariidae	India	Larvae mine leaves
Indarbela spp.	Bark-eating Caterpillars	Metarbelidae	India, S. China	Larvae eat bark & bore branches
Argyroploce aprobola Meyr.	Leaf Roller	Tortricidae	India	Larvae roll leaves
Argyroploce mormopa Meyr.	Leaf Miner	Tortricidae	India	Larvae mine leaves
Metanastria hyrtace C.	Tent Caterpillar	Lasiocampidae	India	Gregarious larvae defoliate
Oenospila flavifusata Wlk.	Looper Caterpillar	Geometridae	India	Larvae defoliate
Carea subtilis W.	Leaf Caterpillar	Noctuidae	India	Larvae defoliate
Euproctis fraterna M.	Tussock Moth	Lymantriidae	India; S.E. Asia	Larvae defoliate
Dacus spp.	Fruit Flies	Tephritidae	India; S.E. Asia	Larvae inside fruits
Holotrichia insularis Bren.	Cockchafer	Scarabaeidae	India	Adults eat leaves
Balaninus c-album	Fruit Weevil	Curculionidae	India	Larvae inside fruits
Nothopeus spp.	Longhorn Beetles	Cerambycidae	Indonesia	Larvae bore trunk

ROSELLE (*Hibiscus sabdariffa* – Malvaceae) (= Jamaican Sorrel; Rama)

This occurs as two distinct botanical varieties. Var. *sabdariffa* is a bushy branched shrub with elongate, pale yellow, edible calyces which are boiled to make a drink, or used in sauces, curries, chutneys, preserves; the leaves may also be used as salad or as a pot herb. Var. *altissima* is a tall, vigorous plant practically without branching 3–5 m tall, grown for fibre in India, Java and the Philippines. The species probably originated in W. Africa, but is now cultivated throughout the tropics, being taken to the New World by the slave trade. The fibres are soft, silky and lustrous, pale brown in colour, and are obtained from the bark of the plant. Roselle grows in any well-drained fertile soil which receives at least 50 cm of rain. The fibre is used as a substitute for jute.

MAJOR PESTS

MINOR PESTS

Maconellicoccus hirsutus (Green)	Hibiscus Mealybug	Pseudococcidae	India	Infest shoots; suck sap; stunt or kill shoots
Cerococcus hibisci Green	Hibiscus Scale	Coccidae	India	Infest foliage
Earias insulana Boisd.	Spiny Bollworm	Noctuidae	India	Larvae bore fruits
Earias vittella (F.)	Spotted Bollworm	Noctuidae	India	Larvae bore fruits
Porthesia scintillans Wlk.	Tussock Moth	Lymantriidae	India	Larvae defoliate
Agrilus acutus Thnb.	Jute Stem Borer	Buprestidae	India	Larvae bore stems

RUBBER (*Hevea brasiliensis* – Euphorbiaceae)

As the name suggests trees are found wild in the tropical rain forests of Brazil in the Amazon basin, adjoining Bolivia and Peru. It was introduced into India, Sri Lanka, Java, Singapore, and Malaysia in the late 19th century, and Africa early in the 20th century. The main areas of production now are S. and C. America, Philippines, Malaysia, C. & W. Africa. The most suitable areas are lowland, hot, wet forests in the tropics, between 15°N and 10°S. It is a quick-growing tree of some 25 m in height in plantations, but growing up to 40 m in the wild. The tree has copious latex in all parts, for which it is cultivated. The latex vessels (modified sieve tubes) under the bark of the trunk are cut diagonally and the exudation collected in cups fastened to the trunk; from this 'tapped' latex is produced natural rubber. (See also Rao 1965.)

MAJOR PESTS				
Melolontha verex Shp.	White Grub	Scarabaeidae	Malaysia	Larvae eat roots; nursery pests
Holotrichia spp.	Chafers	Scarabaeidae	S.E. Asia	
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	Pantropical	Scarify foliage

MINOR PESTS				
Brachytrupes portentosus (Licht.)	Large Brown Cricket	Gryllidae	Malaysia	Seedlings attacked
Zonocerus variegatus L.	Elegant Grasshopper	Acrididae	Africa, W. Indies	Defoliate young trees
Valanga nigricornis (Burm.)	Grasshopper	Acrididae	Malaysia, Indonesia	Defoliate
Macrotermes spp.	Bark-eating Termites	Termitidae	Malaysia	Bark feeders
Pseudacanthotermes militaris (Hagen)	Sugarcane Termite	Termitidae	Africa	Bore inside stems
Coptotermes curvignathus Holmgr.	Rubber Tree Termite	Rhinotermitidae	Malaysia, S.E. Asia	Bore inside live tree trunk
Coptotermes testaceus (L.)	Rubber Tree Termite	Rhinotermitidae	W. Indies, S. America	
Aleuroplatus malayanus	Whitefly	Aleyrodidae	Malaysia	Infest foliage
Planococcus citri Risso	Root Mealybug	Pseudococcidae	Cosmopolitan	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Saissetia spp.	Soft Brown Scales	Coccidae	Pantropical	Infest foliage
Coccus viridis (Green)	Soft Green Scale	Coccidae	Pantropical	Infest foliage
Pulvinaria maxima	–	Coccidae	Malaysia	Infest foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Encrusts foliage
Lepidosaphes cocculi	–	Diaspididae	Malaysia	Encrusts foliage
Laccifer greeni	Lac Insect	Lacciferidae	Malaysia, Sumatra	Infest twigs; protected by ants
Lawana candida F.	Moth Bug	Flattidae	Malaysia	Infest twigs
Scirtothrips dorsalis (Hood)	Chilli Thrips	Thripidae	India, Malaysia	Infest leaves
Heliothrips haemorrhoidalis (Bché.)	Black Tea Thrips	Thripidae	Pantropical	Infest leaves
Acrocercops spp.	Leaf Miners	Gracillariidae	Malaysia	Larvae mine leaves
Thosea sinensis (L.)	Slug Caterpillar	Limacodidae	Malaysia	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Malaysia	Larvae defoliate
Achaea janata (L.)	Castor Semi-looper	Noctuidae	S.E. Asia	Larvae defoliate
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	Malaysia	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantriidae	SE Asia	Larvae eat leaves
Adoxophyes privatana	Shoot Tortrix	Tortricidae	Malaysia	Larvae web shoots
Leucopholis spp.	White Grubs	Scarabaeidae	Malaysia	Larvae eat roots; nursery pests
Lepidiota spp.	White Grubs	Scarabaeidae	Malaysia	
Batocera rufomaculata Deg.	Red-spotted Longhorn	Cerambycidae	India, Sri Lanka	Larvae bore trunk
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	Malaysia	Adults eat leaves
Xyleborus spp.	Black Twig Borers	Solytidae	Pantropical	Adults bore twigs
Polyphagotarsonemus latus (Bank)	Yellow Tea Mite	Tarsonemidae	Pantropical	
Brevipalpus phoenicis (Geijskes)	Red Crevice Tea Mite	Tenuipalpidae	Pantropical	Scarify foliage
Eutetranychus orientalis (Klein.)	Oriental Mite	Tetranychidae	Pantropical	

SAFFLOWER (*Carthamus tinctorius* – Compositae)

This glabrous, somewhat spiny, herbaceous annual looks rather like a thistle with a yellow or orange-coloured flowerhead, and is well known as one of the great tropical crops. A native of India, it is now widely distributed in most warm countries where the climate is not too wet and humid. It is usually grown as a rain-fed crop, and it shows considerable resistance to drought and wind. The flowers are a source of dye (used chiefly in colouring food), the seeds provide an edible oil, and the leaves are used as a salad vegetable. The dye is called safflower carmin, but is fugitive, and now is mostly replaced by aniline dyes. (The dye should not be confused with saffron, which comes from the anthers of a crocus (*Crocus sativus*) in Asia Minor and India.) Most production of safflower is now just for the seed oil (USA), but in Bengal and S. France it is still grown for the dye.

MAJOR PESTS				
Acanthiophilus helianthi Rossi	Safflower Fly	Tephritidae	India, Africa, S. Europe	Larvae bore flower head

MINOR PESTS				
Typhlocyba sp.	Leafhopper	Cicadellidae	India	Infest foliage; suck sap
Empoasca sp.	Leafhopper	Cicadellidae	India, Asia, USA	
Aphis gossypii Glov.	Cotton Aphid	Aphididae	India	
Macrosiphum sonchi L.	Thistle Aphid	Aphididae	Asia	
Dactynotus (carthami) HRL	Safflower Aphid	Aphididae	India, Africa	
Bemisia tabaci (Genn.)	Cotton Whitefly	Aleyrodidae	India	
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	India	
Monanthia globulifera W.	Lace Bug	Tingidae	India	Sap-suckers; with toxic saliva
Lygaeus spp.	Lygaeid Bugs	Lygaeidae	India	
Nezara viridula L.	Green Stink Bug	Pentatomidae	India	
Thrips spp.	Flower Thrips	Thripidae	India, USA, Africa, Asia	Infest flower heads
Microcephalothrips abdominalis (Crawf.)	Thrips	Thripidae	India	Infest flower heads
Frankliniella spp.	Flower Thrips	Thripidae	India, Asia, USA	Infest flower heads
Eublemma spp.	Safflower Semi-loopers	Noctuidae	India, USSR, Africa	Larvae defoliate
Helicoverpa armigera Hb.	American Bollworm	Noctuidae	India	Larvae bore fruits
H. pettigera	Safflower Budworm	Noctuidae	Africa	
Plusia orichalcea Hb.	Cabbage Semi-looper	Noctuidae	India	Larvae defoliate
Spodoptera exigua (Hb.)	Lesser Armyworm	Noctuidae	India, Africa	Larvae defoliate
Trichoplusia ni Hb.	Cabbage Semi-looper	Noctuidae	India, Asia, USA	Larvae defoliate
Phytomyza atricornis (Meign.)	Leaf Miner	Agromyzidae	India	Larvae mine leaves
Melanagromyza obtusa (Mall.)	Bean Pod Fly	Agromyzidae	India	Larvae in flower head
Tanymecus indicus Fst.	Surface Weevil	Curculionidae	India	Adults eat leaves
Acanthiophilus helianthi Russi	Safflower Fly	Tephritidae	Israel	Maggots bore in flower head
Chactorellia jacea (R.D)	Safflower Fly	Tephritidae	Israel	
Larinus spp.	Thistle Weevil	Curculionidae	Asia	Larvae in flower head

SANN HEMP (*Crotalaria juncea* – Leguminosae) (= Sunn Hemp)

An important Asiatic fibre plant, second only in importance to jute as a bast fibre in India where it has been cultivated since ancient times. The bast yields a fibre that is stronger than jute, and more durable. It is essentially a cordage fibre and used in the manufacture of twine, cord, sacking, fishing nets etc. The plant is a shrubby annual legume growing up to 3–4 m in height, with bright yellow flowers. It is very extensively grown in India, about 30% of the crop being exported to the UK and USA. This crop is now being grown extensively throughout the tropics as a green manure and cover crop in orchards, and the dried foliage may be used as livestock fodder, although there are reports that the seeds may be toxic.

MAJOR PESTS

Laspeyresia pseudonectis M.	Stem Borer	Tortricidae	India	Larvae bore stem & shoots
Uthetheisa pulchella L.	Sann Hemp Moth	Arctiidae	India	Larvae defoliate

MINOR PESTS

Bemisia tabaci (Genn.)	Cotton Whitefly	Aleyrodidae	India	Infest foliage
Pinnaspis temporaria Ferris	Armoured Scale	Diaspididae	India	Encrust foliage
Ragmus importunitas Dist.	Sann Hemp Mirid Bug	Miridae	India	Sap-sucker; toxic saliva
Etiella zinckenella Treit.	Pea Pod Borer	Pyralidae	India	Larvae bore pods
Lamprosema indicata F.	–	Pyralidae	India	Larvae eat leaves
Lampides boeticus L.	Pea Blue Butterfly	Lycaenidae	India	Larvae bore pods
Argina spp.	Tiger Moths	Arctiidae	India	Larvae defoliate
Diacrisia obliqua Wlk.	Tiger Moth	Arctiidae	India	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India	Larvae defoliate
Plusia eriosoma D.	Semi-looper	Noctuidae	India	Larvae defoliate
Dasychira mendosa Hb.	Tussock Moth	Lymantriidae	India	Larvae defoliate
Bruchus pisorum L.	Pod Bruchid	Bruchidae	India	Attack ripe pods
Longitarsus belagaumensis F.	Flea Beetle	Chrysomelidae	India	Adults hole leaves
Exora spp.	Leaf Beetles	Chrysomelidae	C. Africa	Adults eat leaves; larvae eat roots

SAPODILLA (*Achras zapota* – Sapotaceae) (= Chiku; Chikoo; Sapota)

A large evergreen tropical forest tree, up to 20 m high, native to Mexico and C. America, known for its delicious fruit and for the milky latex which is the source of chicle, used to make chewing gum. It was taken to the Philippines by the Spaniards, and from there spread to Malaysia and India. Now it is widely cultivated throughout the tropics and sub-tropics of the Old World, as well as Florida and C. America. The fruit is large, rough, and brown in colour, measuring some 8–10 cm in diameter.

A close relative is *Palaquium gutta* in Malaysia, the source of gutta-percha. (See also Butani, 1975*c*.)

MAJOR PESTS

Chloropulvinaria psidii (Mask.)	Guava Mealy Scale	Coccidae	India	Infest foliage
Phenacoccus iceryoides Green	Mealybug	Pseudococcidae	India	Infest foliage
Planococcus lilacinus (Ckll.)	Mealybug	Pseudococcidae	India	Infest foliage
Dacus spp.	Fruit Flies	Tephritidae	India	Larvae inside fruits
Nephopteryx eugraphella Rag.	Chikoo Moth	Pyralidae	India	Larvae web shoots; eat buds & leaves

MINOR PESTS

Idioscopus spp.	Mangohoppers	Cicadellidae	India	Infest foliage
Trialeurodes ricini Misra	Castor Whitefly	Aleyrodidae	India	Infest foliage
Icerya spp.	Fluted Scales	Margarodidae	India	Infest foliage
Planococcus citri (Risso)	Citrus Mealybug	Pseudococcidae	India	Infest foliage
Coccus longulum (Dougl.)	Soft Green Scale	Coccidae	India	Infest leaves
Saissetia oleae Ber.	Black Scale	Coccidae	India	Infest foliage
Frankliniella sulphurea Sch.	Flower Thrips	Thripidae	India	Infest flowers
Indarbela spp.	Bark-eating Caterpillars	Metarbelidae	India	Larvae eat bark & bore wood
Acrocercops gemoniella (Stnt.)	Leaf Miner	Gracillariidae	India	Larvae mine leaves
Virachola isocrates (F.)	Anar Butterfly	Lycaenidae	India	Larvae bore fruits
Rhodoneura spp.	Leaf Webworms	Thyrididae	India	Larvae web leaves
Acrobasis romonella	Bud Borer	Pyralidae	India	Larvae bore buds
Metanastria hyrtaca Cramer	Hairy Caterpillar	Lasiocampidae	India	Larvae defoliate
Phyllophaga consanguinea (Blanch.)	Cockchafer	Scarabaeidae	India	Adults defoliate
Myllocerus undecimpustulatus Faust	Grey Weevil	Curculionidae	India	Adults eat leaves

SESAME (*Sesamum indicum* – Pedaliaceae) (= Simsim; Til; Beniseed; Gingelly)

Sesame is native to Africa, but was taken very early to India. It grows essentially in hot, dry tropical areas of annual rainfall 50–100 cm; it is drought-tolerant. It grows well on poor soils, but prefers sandy-loams. It is sensitive to day-length, and both short- and long-day varieties occur. The plant is a variable erect annual herb, 1–2 m tall, producing capsules containing the small white, red, or black seeds. The seeds contain 45–55% protein; the oil is used for salads and cooking, in soaps, paint, medicines, perfumes, and as a synergist for pyrethrum. The main production areas are India, China, Burma, Sudan, Mexico, Pakistan, Turkey, Venezuela, Uganda, and Nigeria.

MAJOR PESTS

Antigastra catalaunalis (Dup.)	Sesame Webworm	Pyralidae	India, S.E. Asia, S. Europe, Africa	Larvae web & bore pods
Asphondylia sesami Felt	Sesame Gall Midge	Cecidomyiidae	India, E. Africa	Larvae gall pods

MINOR PESTS

Zonocerus variegatus	Elegant Grasshopper	Pyrgomorphidae	Africa	Eat foliage
Aphis gossypii	Cotton Aphid	Aphididae	India	Infest foliage
Myzus persicae (Sulz.)	Peach Aphid	Aphididae	Cosmopolitan	Infest foliage
Bemisia tabaci Genn.	Whitefly	Aleyrodidae	India	Infest foliage
Anoplocnemis curvipes (F.)	Coreid Bug	Coreidae	Africa	
Cyrtopeltis tenuis Reut.	Tomato Mirid	Miridae	India, S.E. Asia	
Taylorilygus vosseleri (Popp.)	Cotton Lygus	Miridae	Africa	
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	Sap-sucker; toxic saliva
Agonoscelis pubescens (Thunb.)	Cluster Bug	Pentatomidae	Africa	
Teleonemia scrupulosa Stal	Lantana Bug	Tingidae	E. Africa	
Stomopteryx subsecivella Zell.	Groundnut Leaf Miner	Gracillariidae	Malaysia	Larvae mine leaves
Maruca testulalis Geyer	Mung Moth	Pyralidae	S.E. Asia, India	Larvae bore pods
Amsacta spp.	Woolly Bears	Arctudae	India	
Estigmene lactinae C.	Woolly Bear	Arctudae	India	Larvae defoliate
Pericallia ricini F.	Woolly Bear	Arctudae	India	
Acherontia styx Wst.	Death's Head Hawk Moth	Sphingidae	Malaysia, India S.E. Asia	Larvae defoliate
Agrotis spp.	Cutworms	Noctuidae	Cosmopolitan	Larvae are cutworms
Helicoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	Cosmopolitan in Old World	Larvae bore pods
& *H. zea*	American Bollworm	Noctuidae	New World	
Sesamia cretica hed.	Sorghum Borer	Noctuidae	Med., Africa	Larvae bore stem
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India, Med., Africa	Larvae defoliate
Anomis flava (F.)	Semi-looper	Noctuidae	Asia, Africa	Larvae defoliate
Thrips spp.	Thrips	Thripidae	E. Africa, India	Infest flowers
Frankliniella spp.	Flower thrips	Thripidae	India	Infest foliage
Henosepilachna elateria (Rossi)	Epilachna Beetle	Coccinellidae	Med.	Defoliate
Aphthona spp.	Flea Beetles	Chrysomelidae	Africa	Seed attacked
Ootheca mutabilis (Sahlb.)	Leaf Beetle	Chrysomelidae	Africa	Defoliate
Tetranychus cinnabarinus (Boisd.)	Carmine Mite	Tetranychidae	S.E. Asia	Scarify foliage
Polyphagotarsonemus latus Banks	Yellow Tea Mite	Tarsonemidae	India	Scarify foliage
Apion spp.	Seed Weevil	Apionidae	Africa	Larvae in Capsule
Baris helleri (Hastm.)	Stem Weevil	Cuculionidae	Africa	Larvae bore stems & pods

SISAL (*Agave sisalana* – Agavaceae)

A native of Mexico and C. America, Sisal is now cultivated in Hawaii, W. Indies, S.E. Asia and many parts of Africa. It is a short-stemmed plant with rows of stiff, sword-like, sharply pointed leaves arranged in a rosette. The fibres for which the plant is cultivated are obtained from the leaves. The plant is very drought-resistant and requires little cultivation, but the first crop is not harvested for seven years. Other species of *Agave* yield inferior fibres and are not grown much, except as ornamentals. (See also Anon, 1965*c*.)

MAJOR PESTS

Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	Malaysia, S. America	Infest leaf bases
Scyphophorus interstitialis Gyll.	Sisal Weevil	Curculionidae	Java, Sumatra, E. Africa, C. America	Larvae bore stem

MINOR PESTS

Nastonotus reductus (Brunn.)	Grasshopper	Tettigoniidae	Venezuela	Damage leaves
Coccus discrepans Gr.	Soft Scale	Coccidae	Malaysia	Infest leaves
Coccus spp.	Soft Green Scales	Coccidae	E. Africa	Infest leaves
Aonidiella sp.	Red Scale	Diaspididae	E. Africa	Infest leaves
Aspidiotus sp.	–	Diaspididae	E. Africa	Infest leaves
Lepidosaphes sp.	Mussel Scale	Diaspididae	E. Africa	Infest leaves
Oryctes rhinoceros (L.)	Rhinoceros Beetle	Scarabaeidae	Malaysia	Adults attack shoots

SORGHUM (*Sorghum bicolor* – Gramineae) (= Great Millet; Guinea Corn; Kaffir Corn; Durra; Milo; Jola)

Sorghum originated in Africa but has long been cultivated in Asia, and is now grown widely in Africa, India, China, Australia and the USA. It is a plant that will grow in semi-desert conditions and so can be grown in areas where maize would fail to establish. It is now the fourth most important cereal crop in the world, following wheat, rice and maize. The plant habit is 1–5 m tall, and like the millets it bears the seed-carrying panicle at the apex of the stem. Red-grained varieties are used to make beer, white-grained ones for flour. It is also used extensively for livestock food. Most is grown for local consumption. Can be grown to maturity in 100 days.

MAJOR PESTS

Homorocoryphus nitidulus Wlk.	Edible Grasshopper	Tettigoniidae	E. Africa	Defoliate & attack panicle
Rhopalosiphum maidis (Fitch)	Corn Leaf Aphid	Aphididae	Cosmopolitan	Infest foliage
Rhopalosiphum sacchari (Zehn.)	Sorghum Aphid	Aphididae	Thailand, China	Infest foliage
Taylorilygus vosseleri (Popp.)	Cotton Lygus	Miridae	Africa	Suck sap from seeds in panicle
Calidea spp.	Blue Bugs	Pentatomidae	Africa	
Chilo orichalcociliella (Strand)	Coastal Stalk Borer	Pyralidae	Africa	Larvae bore stalks
Chilo partellus (Swinhoe)	Spotted Stalk Borer	Pyralidae	India, S.E. Asia	Larvae bore stalks
Eldana saccharina Wlk.	Sugarcane Stalk Borer	Pyralidae	Africa	Larvae bore stalks
Heliothis zea (Boddie)	Cotton Bollworm	Noctuidae	N., C. & S. America	Larvae feed on panicle
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	Old World	
Chloridea obsoleta F.	–	Noctuidae	Malaysia	Larvae defoliate
Sesamia calamistis Hmps.	Pink Stalk Borer	Noctuidae	Africa	Larvae bore stalks
Spodoptera exempta (Wlk.)	African Armyworm	Noctuidae	S.E. Asia	Larvae defoliate
Busseola fusca (Fuller)	Maize Stalk Borer	Noctuidae	Africa	Larvae bore stalks
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	Thailand, Laos, Philippines	Larvae feed on panicle
Contarinia sorghicola (Coq.)	Sorghum Midge	Cecidomyiidae	S.E. Asia	Larvae destroy seeds
Diopsis spp.	Stalk-eyed Flies	Diopsidae	Africa	Larvae bore shoots
Atherigona soccata Rond.	Sorghum Shoot Fly	Muscidae	India, Thailand, Africa	Larvae bore shoots
Atherigona excisa Thomas	Sorghum Shoot Fly	Muscidae	Thailand	Larvae bore shoots
Epilachna similis (Thunb.)	Epilachna Beetle	Coccinellidae	Africa	Adults & larvae eat leaves
Schizonycha spp.	Chafer Grubs	Scarabaeidae	Africa	Larvae eat roots

MINOR PESTS

Locusta migratoria sspp.	Migratory Locusts	Acrididae	Africa, India, Asia	Adults & nymphs eat leaves & attack panicle
Patanga succincta (L.)	Bombay Locust	Acrididae	India, S.E. Asia	
Colemania sphenarioides Bol.	Wingless Grasshopper	Acrididae	India	
Acheta testaceus Wlk.	Field Cricket	Gryllidae	Philippines	Destroy roots & seedlings
Mèlanaphis sacchari (Zehnt.)	Sugarcane Aphid	Aphididae	Pantropical	Infest foliage
Schizaphis graminum (Rond.)	Wheat Aphid	Aphididae	S.E. Asia, Africa, USA, S. America	Infest foliage
Saccharicoccus sacchari (Ckll.)	Sugarcane Mealybug	Pseudococcidae	Pantropical	Infest leaf bases
Peregrinus maidis Ashm.	Maize Planthopper	Delphacidae	Pantropical	Infest foliage
Ricania speculum (Wlk.)	Black Planthopper	Ricaniidae	Philippines	Infest stems
Leptocorisa spp.	Rice Bugs	Miridae	Philippines	Attack grains
Blissus leucopterus (Say)	Chinch Bug	Miridae	USA	Attack grains
Dysdercus spp.	Cotton Stainers	Pyrrhocoridae	Africa	Attack grains
Frankliniella williamsi Hood	Flower Thrips	Thripidae	Thailand	Infest flowers
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Africa	Larvae in panicle

(continued)

MINOR PESTS				
Ephestia sp.	Webworm	Pyralidae	Thailand	Larvae web panicle
Ostrinia furnacalis (Gn.)	Asian Corn Borer	Pyralidae	Malaysia	Larvae bore stalks
Ostrinia nubilalis (Hb.)	European Corn Borer	Pyralidae	Med.	Larvae bore stalks
Diatraea saccharalis (F.)	Sugarcane Borer	Pyralidae	N. & S. America	Larvae bore stalks
Chilo infuscatellus Sn.	–	Pyralidae	India, S.E. Asia	Larvae bore stalks
Chilo sacchariphagus (Boyer)	Sugarcane Stalk Borer	Pyralidae	Malaysia	Larvae bore stalks
Marasmia trapezalis (Gn.)	Maize Webworm	Pyralidae	Pantropical	Larvae web panicle
Stenachroida elongella Wlk.	Sorghum Webworm	Pyralidae	Thailand	Larvae web panicle
Chloridea obsoleta F.	–	Noctuidae	Malaysia	Larvae eat foliage
Celama sorghiella (Riley)	Sorghum Webworm	Nolidae	USA	Larvae eat panicle
Sesamia nonagrioides (Lef.)	–	Noctuidae	Africa	Larvae bore stalk
Sesamia inferens (Wlk.)	Purple Stem Borer	Noctuidae	S.E. Asia	Larvae bore stalks
Sesamia cretica Led.	Sorghum Stem Borer	Noctuidae	Europe, Africa	Larvae bore stalks
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	S.E. Asia	Larvae defoliate & attack panicle
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	
Spodoptera mauritia (Boisd.)	Paddy Armyworm	Noctuidae	Philippines	Larvae defoliate
Elachiptera spp.	Shoot Flies	Chloropidae	E. Africa	Larvae attack young shoots; dead-hearts
Scoliophthalmus spp.	Shoot Flies	Chloropidae	Africa	
Oscinella spp.	Frit Flies	Oscinellidae	Africa	Larvae gall stems
Mylabris spp.	Banded Blister Beetles	Meloidae	India, S.E. Asia, Europe, Africa	Adults eat flowers
Sitophilus oryzae (L.)	Rice Weevil	Curculionidae	Pantropical	Infest panicle
Tanymecus dilaticollis	Southern Grey Weevil	Curculionidae	E. Europe	Damage foliage
Oligonychus indicus Hirst	–	Tetraynchidae	India	Scarify leaves
Alcidodes sp.	Striped Weevil	Curculionidae	Africa	Damage seedlings

SOYBEAN (*Glycine max* – Leguminoseae) (= Soya Bean)

Soybean cultivation originated in the Far East, where it is now the most important legume crop. Much of the world production is for stock feed, but the bean is being increasingly used as a high protein source in human diet. Cultivation in Africa, India, and the Americas is now extensive and increasing; it will grow, as different cultivars, under a wide range of climatic conditions. It is a small bushy, erect, annual which does not produce a tangled growth, with long pendant pods. The seed is the richest natural vegetable food known, and has manifold culinary and agricultural uses. (See also Turnipseed & Kogan, 1976.)

MAJOR PESTS				
Aphis fabae Scop.	Black Bean Aphid	Aphididae	Cosmopolitan	Infest foliage
Empoasca spp.	Green Leafhoppers	Cicadellidae	S.E. Asia, S.E. USA	Infest foliage
Etiella zinckenella (Treit.)	Pea Pod Borer	Pyralidae	Indonesia, China, Laos, Malaysia	Larvae bore pods
Maruca testulalis (Geyer)	Mung Moth	Pyralidae	Pantropical	Larvae bore pods
Epicauta spp.	Blister Beetles	Meloidae	S.E. Asia, USA, Africa, China	Adults eat flowers
Epilachna spp.	Epilachna Beetles	Coccinellidae	S.E. Asia, Africa, USA, S. America	Adults & larvae defoliate
Callosobruchus spp.	Cowpea Bruchids	Bruchidae	Pantropical	Infest ripe pods

MINOR PESTS				
Aphis glycines Mats.	Soybean Aphid	Aphididae	S.E. Asia	Infest foliage
Pseudococcus spp.	Mealybugs	Pseudococcidae	Pantropical	Infest foliage
Dysmicocccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	Pantropical	Infest foliage
Icerya purchasi Mask.	Cottony Cushion Scale	Margarodidae	Pantropical	Infest foliage
Riptortus linearis (L.)	Coreid Bug	Coreidae	Laos, Java, India	Sap-sucker; toxic saliva; destroy seeds
Clavigralla spp.	Spiny Brown Bugs	Coreidae	Africa	
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	Sap-sucker; toxic saliva
Frankliniella spp.	Flower Thrips	Thripidae	India	Infest flowers
Thrips palmae	Palm Thrips	Thripidae	China, S.E. Asia	Infest foliage
Sylepta derogata (F.)	Cotton Leaf-roller	Pyralidae	S.E. Asia	Larvae roll leaves
Elasmopalpus lignosellus (Zell.)	Lesser Cornstalk Borer	Pyralidae	S. USA, C. & S. America	Larvae bore pods
Lamprosema diemenalis (Gn.)	Leaf Roller	Pyralidae	Laos; India	Larvae roll leaves
Heliocoverpa armigera (Hb.)	Old World Bollworm	Noctuidae	Old World tropics	Larvae bore pods
Heliocoverpa zea (Boddie)	Cotton Bollworm	Noctuidae	USA, C. & S. America	Larvae bore pods
Anticarsia gemmatalis (Hub.)	Velvetbean Caterpillar	Noctuidae	S. USA	Larvae bore pods
Agrotis segetum (D. & S.)	Common Cutworm	Noctuidae	Cosmopolitan in Old World	Larvae are cutworms
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	Cosmopolitan	Larvae are cutworms
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Malaysia, Laos	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Plusia orichalcea (F.)	–	Noctuidae	India, Ethiopia, Israel	Larvae defoliate
Trichoplusia ni Hb.	Cabbage Semi-looper	Noctuidae	China	Larvae defoliate
Homona coffearia (Neitn.)	Tea Tortrix	Tortricidae	Papua NG	Larvae roll leaves
Laspeyresia glycinivorella Mats.	Soybean Pod Borer	Tortricidae	S.E. Asia, Japan	Larvae bore pods
Matsumuraeses phaseali (Mats.)	Adzuki Podworm	Tortricidae	Japan, China	
Adoxophyes sp.	Leaf-roller	Tortricidae	Papua NG	Larvae roll leaves
Cydia ptychora Meyr.	African Pea Moth	Tortricidae	Africa	Larvae bore pods
Agrius convolvuli (L.)	Convolvulus Hawk Moth	Sphingidae	China	Larvae defoliate
Porthesia scintillans Wlk.	Tussock Moth	Lymantriidae	Malaysia	Larvae defoliate
Melanagromyza sojae (Zehn.)	Bean Fly	Agromyzidae	S.E. Asia	Larvae bore seedling stems & leaf petioles

(continued)

MINOR PESTS				
Ophiomyia phaseoli (Tryon)	Bean Fly	Agromyzidae	S.E. Asia, Africa, Australasia, India	Larvae stem-bore seedlings & leaf petioles
Epilachna varivestis Mulsant	Mexican Bean Beetle	Coccinellidae	USA, Mexico	Defoliate
Popillia japonica Newm.	Japanese Beetle	Scarabaeidae	China, USA, Canada	Adults defoliate
Mylabris spp.	Banded Blister Beetles	Meloidae	S.E. Asia	Adults deflower
Plagiodera inclusa Stal	Leaf Beetle	Chrysomelidae	S.E. Asia	Adults defoliate
Monolepta nigroapicata	Leaf Beetle	Chrysomelidae	Papua NG	Adults attack foliage
Oberea brevis S.	Stem Borer	Cerambycidae	India	Larvae bore stem
Tetranychus spp.	Red Spider Mites	Tetranychidae	India, China	Scarify leaves

SUGARCANE (*Saccharum officinarum* – Gramineae)

The country of origin is not certain but it is probably somewhere in S.E. Asia; by 327 BC it had become an important crop in India, and was later spread to Egypt and then Spain. It was taken to the New World by Columbus, and is historically important as the original basis of the plantation industry in the tropics and the associated slave trade from Africa to the New World. Now it is grown throughout the tropics and subtropics. It needs a high rainfall (or irrigation) with very fertile soil for the best yields. It is a tall grass, up to 5 m height, with a thick bluish stem and short solid internodes. The cane (stem) has a high sucrose content and is cut annually, the leaves being removed before harvest, by cutting, burning or chemical defoliation. Two or three ratoon crops can be taken before replanting from setts (stem cuttings) is required. It produces more food per hectare than an other crop. The main areas of production are Brazil, India, Cuba, Hawaii, Puerto Rico, Barbados, Guyana, Mauritius and E. Africa. (See also Long & Hensley (1972) and Box (1953).)

MAJOR PESTS				
Hieroglyphus banian (F.)	Large Rice Grasshopper	Acrididae	Thailand, Laos	Defoliate
Pseudacanthotermes militaris (Hagen)	Sugarcane Termite	Termitidae	E. Africa	Damage stems
Microtermes obesi Holmgren	Stem-eating Termite	Termitidae	Thailand	Workers damage stems
Ceratovacuna lanigera Zhnt.	Sugarcane Woolly Aphid	Pemphigidae	China, Taiwan	Sap-suckers
Aulacaspis tegalensis (Zehn.)	Sugarcane Scale	Diaspididae	S.E. Asia, E. Africa	Encrust stems
Saccharicoccus sacchari (Ckll.)	Sugarcane Mealybug	Pseudococcidae	Pantropical	Infest stems
Perkinsiella saccharicida (Ckll.)	Sugarcane Planthopper	Delphacidae	S.E. Asia, S. Africa, Madagascar, Australia	Sap-sucker; virus vector
Pyrilla perpusilla Wlk.	Indian Sugarcane Planthopper	Lophopidae	India, Thailand	Sap-sucker
Tomaspis spp. }	Sugarcane Spittlebugs	Cercopidae	C. & S. America	Sap-suckers
Aeneolamia spp. }	Sugarcane Spittlebugs	Cercopidae	C. & S. America	Sap-suckers
Chilo orichalcociliella (Strand)	Coastal Stalk Borer	Pyralidae	Africa	Larvae bore stems
Chilo partellus (Swinhoe)	Spotted Stalk Borer	Pyralidae	India, S.E. Asia, Africa, Pakistan	Larvae bore stems
Chilo sacchariphagus (Boyer)	Sugarcane Stalk Borer	Pyralidae	S.E. Asia, China	Larvae bore stems
Eldana saccharina Wlk.	Sugarcane Stalk Borer	Pyralidae	Africa	Larvae bore stems
Diatraea saccharalis (F.)	Sugarcane Borer	Pyralidae	N. & S. America	Larvae bore stems
Sesamia inferens (Wlk.)	Purple Stalk Borer	Noctuidae	India, S.E. Asia, China	Larvae bore stems
Sesamia calamistis (F.)	Pink Stalk Borer	Noctuidae	Africa	Larvae bore stems
Leucopholis spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots
Dermolepida albohirtum Waterh.	Grey-back Cane Beetle	Scarabaeidae	Australia (Queensland)	Larvae eat roots
Cochliotis melolonthoides (Ger.)	Sugarcane White Grub	Scarabaeidae	E. Africa	Larvae eat roots
Schizonycha spp.	Chafer Grubs	Scarabeidae	Africa	Larvae eat roots
Dorystenes buqueti Gn.	Longhorn Beetle	Cerambycidae	Thailand	Larvae bore stems

MINOR PESTS				
Acheta testaceus (Wlk.)	Field Cricket	Gryllidae	Philippines	Attack roots
Gryllotalpa spp.	Mole Cricket	Gryllotalpidae	S.E. Asia	Attack roots
Macrotermes spp.	Bark Termites	Termitidae	Africa, India, S.E. Asia	Damage foliage
Heterotermes spp.	Moist Wood Termite	Rhinotermitidae	Philippines, C. & S. America	Damage roots & stems
Microcerotermes annandalei Silvestri	–	Termitidae	Thailand	Damage roots & stems
Odontotermes obesus Ramb.	Scavenging Termite	Termitidae	India, Pakistan	Damage foliage
Odontotermes spp.	Scavenging Termites	Termitidae	India, S.E. Asia, China, Africa	Damage foliage

(continued)

Mogannia hebes Wlk.	Grass Cicada	Cicadidae	Taiwan, Okinawa	Nymphs suck sap from roots
Rhopalosiphum maidis (Fitch)	Corn Leaf Aphid	Aphididae	Pantropical	Infest foliage
Sipha spp.	Aphids	Aphididae	India	Infest foliage
Melanaphis sacchari Zehnt.	Sugarcane Aphid	Aphididae	Pantropical	Infest foliage
Oregma sp.	Woolly Aphid	Pemphigidae	Thailand	Infest foliage
Cicadella spectra (Dist.)	White Jassid	Cicadellidae	Africa, India, S.E. Asia	Infest foliage
Cicadulina mbila (Naude)	Maize Leafhopper	Cicadellidae	Africa	Infest foliage
Matsumuratettrix hiroglyphicus (Mats.)	Sugarcane Leafhopper	Cicadellidae	Taiwan	Infest foliage
Laodelphax striatella Fall.	Small Brown Planthopper	Delphacidae	S.E. Asia	Sap-suckers; virus vectors
Saccharosydne spp.	Sugarcane Planthoppers	Delphacidae	China, W. Indies	
Numicia viridis Muir	–	Trophiduchidae	S. Africa	Infest foliage
Phenice moesta Westw.	–	Fulgoridae	Malaysia	Sap-sucker
Aleurolobus barodensis Mask.	Sugarcane Whitefly	Aleyrodidae	India	Sap-sucker
Brevennia rehi (Ldgr.)	Rice Mealybug	Pseudococcidae	India, S.E. Asia, S. USA	Infests roots
Dysmicoccus brevipes (Ckll.)	Pineapple Mealybug	Pseudococcidae	Egypt, Pacific	
Dysmicoccus boninsis (Kuw.)	Grey Sugarcane Mealybug	Pseudococcidae	Pantropical	Sap-suckers; in colonies under leaf sheaths
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	
Pseudococcus adonidum (L.)	Long-tailed Mealybug	Pseudococcidae	Pantropical	
Planococcus kenyae (Le Pell.)	Kenya Mealybug	Pseudococcidae	E. Africa	
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	Encrust stems
Nisia atrovenosa (Leth.)	–	Menopliidae	Laos	Sap-sucker
Diostrombus dilatatus West.	–	Derbidae	E. Africa	Sap-sucker
Hercinothrips femoralis (Reut.)	Banded Greenhouse Thrips	Thripidae	Cosmopolitan	Infest foliage
Phragmataecia castaneae Hb.	Moth Borer	Cossidae	Malaysia	Larvae bore stems
Castnia licas (Drury)	Giant Moth Borer	Castniidae	S. America	Larvae bore stems
Eucosma isogramma Meyr.	Bud Moth	Eucosmidae	Malaysia	Larvae bore shoots
Marasmia trapezalis (Gn.)	Maize Webworm	Pyralidae	Pantropical	Larvae defoliate
Tryporyza nivella (F.)	White Tip Borer	Pyralidae	India, S.E. Asia, China	Larvae bore shoots
Tryporyza spp.	Stem Borers	Pyralidae	S.E. Asia	Larvae bore stems
Chilo polychrysa (Meyr.)	Spotted Stalk Borer	Pyralidae	India, S.E. Asia	Larvae bore stems
Chilo infuscatellus Sn.	Yellow Tip Borer	Pyralidae	India, S.E. Asia	Larvae bore shoots
Sesamia nonagrioides (Lef.)	–	Noctuidae	Africa	Larvae bore stalks
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Malaysia	Larvae defoliate
Spodoptera mauritia (Boisd.)	Paddy Armyworm	Noctuidae	S.E. Asia, Australasia	Larvae defoliate
Remigia repanda (F.)	Guinea Grass Moth	Noctuidae	C. & S. America	Larvae defoliate
Mythimna spp.	Rice Armyworms	Noctuidae	Cosmopolitan	Larvae defoliate
Panara spp.	Skipper Butterflies	Hesperiidae	Philippines	Larvae roll leaves
Telicota augias (L.)	Rice Skipper	Hesperiidae	India, S.E. Asia, Australasia	Larvae fold leaves
Heteronychus spp.	Black Cereal Beetles	Scarabaeidae	Africa	Adults eat young stems, larvae eat roots
Adoretus spp.	White Grubs	Scarabaeidae	S.E. Asia	Larvae live in soil and eat roots; especially damaging to young plants
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	
Lepidiota stigma F.	Cane Grub	Scarabaeidae	Thailand, Laos	
Lepidiota discendens Sharp	Cane Grub	Scarabaeidae	Laos	
Lepidiota spp.	White Grubs	Scarabaeidae	S.E. Asia, Australasia	
Protaetia fusca Hbst.	Flower Beetle	Scarabaeidae	Malaysia, Indonesia	Adults feed on flowers
Oryctes spp.	Rhinoceros Beetles	Scarabaeidae	Africa, India	Adults damage shoots
Opatrum spp.	False Wireworms	Tenebrionidae	Philippines	Adults eat leaves; larvae soil pests

Lacon spp.	Sugarcane Wireworms	Elateridae	Australia	Larvae eat roots
Melanotus tamsuyensis Bates	Sugarcane Wireworm	Elateridae	Taiwan	Larvae eat roots
Chlorophorus annularis (F.)	Bamboo Longhorn Beetle	Cerambycidae	S. China	Larvae bore stem
Rhabdoscelis obscurus Boisd.	Cane Weevil Borer	Curculionidae	Australasia	Larve bore stems
Metamasius hemipterus L.	West Indian Cane Weevil	Curculionidae	Africa, W. Indies	Larvae bore stems
Sepiomus sp.	Leaf-eating Weevil	Curculionidae	Thailand	Adults eat leaves
Paratetranychus exsiccator Zehnt.	Spider Mite	Tetranychidae	Indonesia, Philippines	Scarify foliage
Tarsonemus bancrofti Mich.	Cane Blister Mite	Tarsonemidae	Indonesia, Philippines, Australia, Hawaii, Florida, S. America	Shoots damaged

SUNFLOWER (*Helianthus annuus* – Compositae)

Sunflower is not known in the truly wild state, but possibly originated in Utah, Arizona or S. California. It was taken to Europe in 1510 and to Russia in the 18th century, and is now grown in most tropical and temperate countries. It is grown from the Equator to 55°N; and can withstand a slight frost. In the tropics it grows best at medium to high elevations; it is not suited to the wet tropics. It can grow in very dry areas in a variety of soils. It is a variable annual herb 0.7–3.5 m tall. Giant, semi-dwarf, and dwarf varieties are grown. The large flower head, with yellow petals, produces a disc of ovoid achenes, white, black, or striped in colour. The seeds are rich in oil (25–35%) and linoleic acid, and 13–20% protein. The decorticated cake is also rich in protein. Seeds can be eaten raw, roasted, or fed to stock; the oil is used in cooking and for margarine. The main areas of production are USSR, Argentina, Romania, Bulgaria, Hungary, Yugoslavia, Turkey, S. Africa, Uruguay, Tanzania, Kenya, Zimbabwe, and Australia. (See also Rajamohan, 1976.)

MAJOR PESTS				
Calidea spp.	Blue Bugs	Pentatomidae	Africa	Sap-suckers; toxic saliva
Helicoverpa armigera (Hub.)	Old World Bollworm	Noctuidae	Cosmopolitan in Old World	Larvae feed on seeds
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Australia	Suck sap from seeds
Schizonycha spp.	Chafer Grubs	Scarabaeidae	Africa	Larvae eat roots

MINOR PESTS				
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Australia	Infest foliage
Clastoptera xanthocephala Germ.	Spittlebug	Cercopidae	USA	Sap-suckers
Amrasca terraereginae (Paoli)	Leafhopper	Cicadellidae	Australia	Infest foliage
Empoasca spp.	Leafhoppers	Cicadellidae	Australia	Infest foliage
Nysius spp.	–	Lygaeidae	Australia }	Sap-suckers; toxic saliva
Agonoscelis pubescens Thnb.	Cluster Bug	Pentatomidae	Africa }	
Homoeosoma electellum (Hulst)	Sunflower Moth	Phycitidae	USA	Larvae eat seeds
Agrius convolvuli (L.)	Convolvulus Hawk	Sphingidae	Old World	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	Asia, Australasia	Larvae defoliate
Heliothis peltigera D. & S.	Budworm	Noctuidae	India	Larvae eat young florets
Heliothis punctigera Wllgr.	Native Budworm	Noctuidae	Australia	Larvae bore buds
Lasioptera murtfeldtiana Felt	Sunflower Seed Midge	Cecidomyiidae	USA	Larvae gall seeds
Dacus cucurbitae Coq.	Melon Fly	Tephritidae	Africa, Asia, Australasia	Larvae in flower head
Strauzia longipennis (Wied.)	Sunflower Maggot	Tephritidae	USA	Larvae in flower head
Epilachna spp.	Epilachna Beetles	Coccinellidae	Africa	Defoliate
Zygospila exclamationis (F)	Sunflower Beetle	Chrysomelidae	USA	Defoliate
Gonocephalum macleayi Blkb.	Southern False Wireworm	Tenebrionidae	Australia	Larvae eat roots

SWEET POTATO (*Ipomoea batatas* – Convolvulaceae)

This is not known in the wild state but is thought to have come from C. or S. America. It is now widely cultivated throughout the tropics from about 40° N to 32° S, from sea-level to about 500 m mostly. Best growth is where the average temperature is 24°C or over, with a well-distributed rainfall of 75–125 cm per annum. It is a short-day plant, with a photoperiod of 11 hours or less promoting flower formation. The plant is a perennial herb cultivated as an annual vine with trailing stems 1–5 m long. It produces about 10 tubers per plant in the top 20 cm of soil by secondary thickening of the roots. The tubers do not store well so are usually harvested gradually as required. The tubers are an important staple food, and may also be processed for starch, glucose or alcohol. Leaves and vines are used for cattle food. Most cultivation is in Africa, but it is also extensive in China, Japan, USA and New Zealand. (See also Butani & Varma, 1976*c*.) Tubers are exported to Europe now.

MAJOR PESTS				
Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	Cosmopolitan	Infest foliage
Synanthedon dasysceles Bradley	Sweet Potato Clearwing	Sesiidae	Africa	Larvae bore vines
Omphisa anastomosalis Guen.	Sweet Potato Stem Borer	Pyralidae	Malaysia, Laos, India, Indonesia, China	Larvae bore vines
Agrius convolvuli (L.)	Convolvulus Hawk	Sphingidae	Old World	Larvae defoliate
Acraea acerata Hew.	Sweet Potato Butterfly	Nymphalidae	E. Africa, Zaïre	Larvae defoliate
Aspidomorpha spp.	Tortoise Beetles	Chrysomelidae	Africa, Asia	Adults & larvae defoliate
Metriona circumdata (Herbst.)	Green Tortoise Beetle	Chrysomelidae	S.E. Asia, China, India	Adults & larvae defoliate
Metriona sp.		Chrysomelidae	S. America	
Alcidodes dentipes (Ol.)	Sweet Potato Weevil	Curculionidae	Africa	Adults eat stems; larvae gall stems
Cylas formicarius (F.)	Sweet Potato Weevil	Apionidae	Pantropical	Adults & larvae bore tubers
Cylas puncticollis Boh.	Sweet Potato Weevil	Apionidae	Africa	Adults & larvae bore tubers
MINOR PESTS				
Locusta migratoria sspp.	Migratory Locusts	Acrididae	Africa, India, S.E. Asia	
Oxya spp.	Small Rice Grasshoppers	Acrididae	S.E. Asia, China	Adults & nymphs defoliate
Catantops humilis Serv.	Grasshopper	Acrididae	Malaysia	
Zonocerus variegatus L.	Variegated Grasshopper	Acrididae	Africa	
Phymateus aegrotus Gerst.	Stink Grasshopper	Acrididae	Africa	
Empoasca spp.	Green Leaf-hoppers	Cicadellidae	S.E. Asia, China, Africa	Infest foliage
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Cosmopolitan	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Planococcus kenyae (Le Pell.)	Kenya Mealybug	Pseudococcidae	E. & W. Africa	Infest foliage
Geococcus coffeae Green	Root Mealybug	Pseudococcidae	India	Infest roots
Orthezia insignis Browne	Jacaranda Bug	Orthezidae	Pantropical	Infest foliage
Helopeltis spp.	Helopeltis Bugs	Miridae	Africa	
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	S.E. Asia	Sap-suckers; toxic saliva
Anoplocnemis sp.	Coreid Bug	Coreidae	S.E. Asia	
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	
Frankliniella schulzei (Trybom)	Flower Thrips	Thripidae	Africa	Infest flowers
Synanthedon spp.	Sweet Potato Clearwings	Sesiidae	Africa	Larvae bore vines
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	S.E. Asia, China, Australasia	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa	Larvae defoliate
Mythimna spp.	Rice Armyworms	Noctuidae	S.E. Asia	Larvae defoliate
Diacrisia spp.	Tiger Moths	Arctiidae	India, S.E. Asia, Africa	Larvae defoliate
Hyles lineata (Esp.)	Striped Hawk	Sphingidae	Africa	Larvae defoliate
Hippotion celerio (L.)	Silver-striped Hawk Moth	Sphingidae	Africa	Larvae defoliate
Adoxophyes sp.	Leaf Roller	Tortricidae	Papua NG	Larvae roll leaves
Ascotis reciprocaria (Wlk.)	Coffee Looper	Geometridae	E. & S. Africa	Larvae defoliate

(continued)

Bedellia spp.	Leaf Miners	Lyonetidae	Africa, Hawaii, USA, Australia	Larvae mine leaves Cosmopolitan
Aciptilia sp.	Vine Borer	Pterophoridae	S. China	Larvae bore vines
Ochyrotica sp.	Leaf Roller	Pterophoridae	S. China	Larvae roll leaves
Parasa vivida (Wlk.)	Nettlegrub	Limacodidae	Africa	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantriidae	Africa	Larvae defoliate
Epilachna spp.	Epilachna Beetles	Coccinellidae	S.E. Africa	Adults & larvae defoliate
Anomala spp.	White Grubs	Scarabaeidae	S.E. Asia	
Apogonia cribricollis Burm.	Chafer Beetle	Scarabaeidae	Malaysia	Larvae attack roots & tubers; adults may eat leaves
Leucopholis spp.	White Grubs	Scarabaeidae	Philippines	
Lachnosterna sp.	June Beetle	Scarabaeidae	USA, C. & S. America	
Epicauta spp.	Blister Beetles	Meloidae	S America	
Mylabris spp.	Blister Beetles	Meloidae	S. E. Asia	Adults deflower
Lacoptera chinensis (F.)	Tortoise Beetle	Chrysomelidae	S. China	Adults & larvae defoliate
Diabrotica balteata Lec.	Cucumber Beetle	Chrysomelidae	Pacific, C. & S. America	Larvae eat roots
Heteroderes laurenti Guer.	Gulf Wireworm	Elateridae	S. USA, C. & S. America	Larvae damage roots & defoliate
Megastes grandalis Gn.	Moth	?	C. & S. America	Larvae bore stem and tubers
Typophorus viridicyanus (Crotch)	Leaf Beetle	Chrysomelidae	S. USA	Adults & larvae eat leaves
T. nigritus	Leaf Beetle	Chrysomelidae	Argentine	Major pest of stored roots
Euscepes postfasciatus Fairm.	West Indian Sweet Potato Weevil	Curculionidae	Pacific, W. Indies, S. America	Larvae bore tubers
Blosyrus ipomocae Mahl.	Sweet Potato Leaf Weevil	Curculionidae	China, India, Africa	Adults eat leaves
Melanagromyza coerulea (Malloch)	Leaf Miner	Agromyzidne	Peru	Leaf miner
Tetranychus cinnabarinus (Boisd.)	Carmine Mite	Tetranychidae	Pantropical	Scarify leaves
Ptericoptus sinuatus Berg.	?		Paraguay	Stem borer

TAMARIND (*Tamarindus indica* – Caesalpiniaceae)

This large leguminous tree, growing to a height of 25 m, probably originated in tropical Africa or southern Asia in semi-arid regions; it is now widely grown throughout the drier tropics, both for the pods and as a shade or ornamental tree. The curved oblong pod, about 8 × 2 cm, is characteristically constricted and contains 2–5 brown obovate seeds (sometimes more). The pulp around the seeds is tart and brown in colour, and may be eaten fresh, mixed with sugar to make a sweetmeat, used in seasoning as well as curries, sauces, preserves, and chutneys, and also makes a refreshing acid drink. The seeds may be eaten after the removal of the test and boiling or roasting. In India the seeds may be used to make flour, and as a source of carbohydrate for sizing cloth and for vegetable gum. Most cultivation takes place in India, W. Indies and Florida. (See also Butani, 1978*b*.)

MAJOR PESTS				
Drosichiella tamarindus (Gr.)	Tamarind Mealybug	Margarodidae	India	Encrust foliage
Planococcus lilacinus (Ckll.)	Mealybug	Pseudococcidae	India	Encrust foliage
Saissetia oleae Ber.	Black Scale	Coccidae	India	Encrust foliage
Aonidiella orientalis (New.)	Oriental Yellow Scale	Diaspididae	India	Encrust foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	India	Encrust foliage
MINOR PESTS				
Toxoptera aurantii (Fon.)	Black Citrus Aphid	Aphididae	India	Infest foliage
Nipaecoccus spp.	Mealybugs	Pseudococcidae	India	Encrust foliage
Aspidiotus tamarindi Gr.	Tamarind Scale	Diaspididae	India	Encrust foliage
Pinnaspis spp.	Armoured Scales	Diaspididae	India	Encrust foliage
Kerria lacca (Kerr)	Lac Insect	Lacciferidae	India	Encrust twigs
Drosicha stebbingi (Gr.)	Giant Mealybug	Margarodidae	India	Encrust foliage
Scirtothrips dorsalis Hood	Chilli Thrips	Thripidae	India	Infest buds & flowers
Laspeyresia palamedes Meyr.	Flower Webber	Tortricidae	India	Larvae bore buds; web flowers & buds
Argyroploce illepida Bult.	Fruit Borer	Tortricidae	India	Larvae bore pods
Virachola isocrates (F.)	Anar Butterfly	Lycaenidae	India	Larvae bore pods
Dichocrocis punctiferalis (Guen.)	Castor Capsule Borer	Pyralidae	India	Larvae bore pods
Assara albicostalis Wlk.	–	Pyralidae	India	Larvae bore pods
Etiella zinckenella Treit.	Pea Pod Borer	Pyralidae	India	Larvae bore pods
Eublemma angulifera Moore	Flower Webber	Noctuidae	India	Larvae damage flowers
Alphitobius laevigiatus (F.)	–	Tenebrionidae	India	Larvae bore dry pods
Ulomo sp.	–	Tenebrionidae	India	Larvae inside pods
Caryedon serratus (Ol.)	Groundnut Beetle	Bruchidae	Africa	Larvae inside pods

TARO *(Colocasia esculenta* – Araceae) (= Cocoyam; Dasheen)

C. esculenta occurs wild in S.E. Asia, and in early times was taken to China and Japan; it was taken to the Mediterranean region in biblical times and then spread to W. Africa. It is an important staple crop throughout the Pacific region, and in the W. Indies and W. Africa. The corms are roasted, baked, or boiled, and have a high content of tiny, easily digestible, starch grains; the young leaves are sometimes eaten as a vegetable. It occurs as two fairly distinct varieties and a large number of clones, and is probably best regarded as a polymorphic single species. The plant is a herb, 1–2 m tall, with an underground starchy corm; the leaves are large and spade-shaped, with the margin entire, and a long fleshy petiole. Many cultivars do not flower, and propagation is generally vegetative; in the wild pollination is probably effected by flies. Several edible aroids are grown in Pacific Region.

MAJOR PESTS				
Tarophagus proserpina (Kir.)	Taro Planthopper	Delphacidae	S.E. Asia, Pacific Isl.	Infest leaves; virus vector
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	India, S.E. Asia	Larvae eat leaves
Papuana laevipennis Arrow	Taro Beetle	Scarabaeidae	Papua NG, Solomon Isl.	Larvae bore coms
Monolepta signata Oliv.	White-spotted Flea Beetle	Chrysomelidae	India	Adults hole leaves
MINOR PESTS				
Gesonia spp.	Aquatic Grasshoppers	Acrididae	Papua NG, India	Defoliate
Bemisia tabaci	Tobacco Whitefly	Aleyroclidae	Pantropical	Suck sap
Cicadella sp.	Leafhopper	Cicadellidae	Papua NG	Infest foliage
Aphis gossypii Glov.	Cotton Aphid	Aphididae	S.E. Asia, India,	Infest foliage, virus vectors
Myzus persicae	Peach Aphid	Aphididae	Cosmopolitan	Infest foliage
Pentalonia nigronervosa Coq.	Banana Aphid	Aphididae	S.E. Asia, India	Infest foliage
Dysmicoccus brevipes (Ckll.)	Pineapple	Pseudococcidae	Philippines	Infest foliage; virus vectors
Planococcus spp.	Mealybug	Pseudococcidae	Pantropical	Infest foliage; virus vectors
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Philippines	Infest foliage
Stephanitis typicus Dist.	Banana Lace Bug	Tingidae	India	Sap-sucker; toxic saliva
Heliothrips haemorrhoidalis (Bché.)	Black Tea Thrips	Thripidae	India	Infest foliage
Caliothrips indicus (Bagn.)	Leaf Thrips	Thripidae	India	Infest foliage
Agrius convolvuli (L.)	Sweet Potato Hawk Moth	Sphingidae	Philippines	Larvae defoliate
Hyloicus pinastri (L.)	Pine Hawk Moth	Sphingidae	Papua NG	Larvae defoliate
Hippotion celerio (L.)	Silver-striped Hawk	Sphingidae	S.E. Asia, India, Africa	Larvae defoliate
Papuana huebneri	Taro Beetle	Scarabaeidae	Papua NG	Larvae & adults bore corns
Ligyrus spp.		(Dynastinae)	C. & S. America	

TEA (*Thea sinensis* – Theaceae) (= *Camellia sinensis*)

Tea originated near the source of the river Irriwaddy and spread to S.E. China, Indo-China and Assam where wild teas can still be found. The main centres of early cultivation were in S.E. Asia and China, but now the crop is grown in many parts, mainly in the sub-tropics and in the mountain regions of the tropics (e.g. at 1–2000 m at the Equator). It needs equable temperatures, moderate to high rainfall and high humidity all the year round, and cannot tolerate frost. It is a small evergreen tree which can grow to 15 m high, but is pruned to a bush of 0.5–1.5 m. The leaves and buds are picked and dried and treated in various ways according to which type of tea is being produced. The leaves contain caffeine, polyphenols and essential oils. The main production areas are India, Sri Lanka, China, Indonesia, Taiwan, Japan, Kenya, Malawi, Uganda, Tanzania, Mozambique, USSR and Argentina. (See also Cranham, 1966*b*.) Assam varieties more susceptible to some pests than Chinese varieties.

MAJOR PESTS

Brachytrupes membranaceus (Drury)	Tobacco Cricket	Gryllidae	Africa	
Brachytrupes portentosus Licht.	Large Brown Cricket	Gryllidae	India, China	Adults & nymphs destroy seedlings; nursery pests mostly
Gryllotalpa africana Pal.	African Mole Cricket	Gryllotalpidae	S.E. Asia, Africa, Australasia	
Helopeltis schoutedeni Reuter	Cotton Helopeltis	Miridae	Africa	Sap-sucker; toxic saliva
Heliothrips haemorrhoidalis (Bouché)	Black Tea Thrips	Thripidae	Cosmopolitan	Scarify leaves
Homona coffearia Nietn.	Tea Tortrix	Tortricidae	India, Sri Lanka, Indonesia	Larvae roll leaves
Aperitmetus brunneus (Hust.)	Tea Root Weevil	Curculionidae	Kenya, Somalia	Larvae bore roots
Xyleborus fornicatus Eichh.	Tea Shot-hole Borer	Scolytidae	India, Sri Lanka, S.E. Asia	Adults bore stems
Brevipalpus phoenicis (Geijskes)	Red Crevice Tea Mite	Tenuipalpidae	Pantropical	Distort leaves
Oligonychus coffeae (Neitn.)	Red Coffee Mite	Tetranychidae	India, S.E. Asia, Australasia, C. & S. America	Scarify leaves, heavy infestation distort growth, may defoliate
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	India, S.E. Asia, Europe, USA, C. America	
Calacarus cairnatus (Green)	Purple Mite	Eriophyidae	India, S.E. Asia, Japan, USA.	

MINOR PESTS

Odontotermes spp.	Scavenging Termites	Termitidae	India, Malaysia, China, Africa	Eat bark and leaves
Microcerotermes spp.	Live Wood-eating Termites	Termitidae	India, Malaysia, Java	Bore stems & eat live wood
Kalotermes spp.	Dry-wood Termites	Kalotermitidae	India, Sri Lanka	Live in dead wood; sometimes pests
Chlorita onukii	Tea Green Leafhopper	Cicadellidae	Japan	Infest foliage
Toxoptera aurantii (B. de F.)	Black Citrus Aphid	Aphididae	Cosmopolitan	Infest foliage
Ceroplastes rubens Mask.	Pink Waxy Scale	Coccidae	India, S.E. Asia, China	Infest twigs and leaves
Coccus viridis Green	Soft Green Scale	Coccidae	Pantropical	Infest twigs & leaves
Coccus hesperidum L.	Soft Brown Scale	Coccidae	Cosmopolitan	Infest twigs & leaves
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Cosmopolitan	Infest twigs & leaves
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Widespread	
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	Pantropical	
Selanaspidus spp.	Armoured scales	Diaspididae	E. Africa	Encrust foliage
Chrysomphalus aonidum (L.)	Purple Scale	Diaspididae	Malawi	

(continued)

Fiorinia theae Green	Tea Scale	Diaspididae	India	Encrust foliage
Helopeltis antonii Sign.	Tea Mosquito Bug	Miridae	India, S.E. Asia	Sap-suckers; toxic saliva
Helopeltis theivora Waterh.	Tea Capsid Bug	Miridae	India, S.E. Asia	
Helopeltis bergrothi Reut.	Cocoa Mosquito Bug	Miridae	Africa	
Poecilocoris latus Dall.	Tea Seed Bug	Pentatomidae	India, Indo-China	
Zeuzera coffeae Neitn.	Red Coffee Borer	Cossidae	Sri Lanka, Malaysia	Larvae bore stems
Gracillaria theivora (Wlsm.)	Tea Leaf Roller	Gracillariidae	India	Larvae roll leaves
Scrobipalpa heliopa (Lowes)	Tobacco Stem Borer	Gelechiidae	India, SE Asia	Larvae bore stems
Adoxophyes orana (F.v.S.)	Smaller Tea Tortrix	Tortricidae	Japan	Larvae defoliate
Cryptophlebia leucotreta (Meyr.)	False Codling Moth	Tortricidae	Africa	Larvae roll leaves
Cydia leucostoma (Meyr.)	Tea Flushworm	Tortricidae	India, Sumatra, Java, Taiwan	Larvae defoliate
Tortrix dinota Meyr.	Brown Tortrix	Tortricidae	Malawi	Larvae defoliate
Clania cramerii Westw.	Bagworm	Psychidae	India, China	Larvae defoliate
Caloptilia theivora	Tea Leaf Roller	Pyralidae	Japan	Larvae roll leaves
Andraca bipunctata Wlk.	Bunch Caterpillar	Bombycidae	India	Larvae defoliate
Eterusia magnifica Butl.	Red Slug Caterpillar	Zygaenidae	India, S.E. Asia	Larvae defoliate
Euproctis spp.	Tussock Moths	Lymantriidae	India, Japan, China	Larvae defoliate
Agrotis segetum (D. & S.)	Common Cutworm	Noctuidae	Old World	Nursery pest
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia	Larvae defoliate
Biston suppressaria Guen.	Common Looper	Geometridae	India	Larvae defoliate
Niphadolepis alianta Karsch.	Jelly Grub	Limacodidae	Malawi	Larvae defoliate
Setora nitens (Wlk.)	Stinging Caterpillar	Limacodidae	S.E. Asia	Larvae defoliate
Parasa vivida (Wlk.)	Stinging Caterpillar	Limacodidae	E. & W. Africa	Larvae defoliate
Parasa lepida Cram.	Blue-striped Nettlegrub	Limacodidae	India, S.E. Asia	Larvae defoliate
Thosea spp.	Stinging Caterpillars	Limacodidae	India	Larvae defoliate
Attacus atlas L.	Atlas Moth	Saturniidae	India, Indonesia, S. China	Larvae defoliate
Tropicomyia theae (Cotes)	Tea Leaf Miner	Agromyzidae	India, Java, China	Larvae mine leaves
Gonocephalum simplex (F.)	Dusty Brown Beetle	Tenebrionidae	Africa	Adults damage stems
Holotrichia seticollis Moser	Chafer Grub	Scarabaeidae	India	Larvae eat roots; nursery pest
Xylosandrus compactus Eidh.	Stem Borer	Scolytidae	SriLanka	Adults bore stems
Brevipalpus californicus (Banks)	–	Tenuipalpidae	Cosmopolitan	Scarify leaves
Eriophyes theae Watt.	Tea Blister Mite	Eriophyidae	India, Indonesia	Form blisters (erinia) on leaves

TOBACCO (*Nicotiana tabacum* – Solanaceae)

Probably Tobacco originated in N.W. Argentina, but it was cultivated in pre-Columbian times in the W. Indies, Mexico, C. and S. America. By the 17th century it had been spread to India, Africa, Japan, Philippines and the Middle East. It is now very widely cultivated throughout the warmer parts of the world, from central Sweden in the north down to southern Australia. The crop needs 90–120 frost-free days from transplanting to harvest. The optimum mean temperature for growth is 20–26°C; strong illumination is needed; it can grow in as little as 25 cm of rain, but prefers 50 cm. Dry weather is essential for ripening and harvest. The plant is a perennial herb 1–3 m tall, usually grown as an annual for its leaves which are cured to make tobacco and snuff. The main production areas are USA, Brazil, Japan, Canada, Pakistan, India, Greece, Turkey and Zimbabwe.

MAJOR PESTS

Brachytrupes membranaceus Drury	Tobacco Cricket	Gryllidae	Africa	Destroy seedlings
Gryllotalpa spp.	Mole Crickets	Gryllotalpidae	Cosmopolitan	Eat roots
Bemisia tabaci (Genn.)	Whitefly	Aleyrodidae	Cosmopolitan	Infest leaves underworth
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Scarify leaves
Helicoverpa armigera (Hbn.)	Old World Bollworm	Noctuidae	Cosmopolitan in Old World	Larvae bore buds, & eat leaves
Helicoverpa zea (Boddie)	Cotton Bollworm	Noctuidae	N., C. & S. America	Larvae eat leaves
Agrotis ipsilon (Hfn.)	Black Cutworm	Noctuidae	Cosmopolitan	Larvae cutworms
Manduca sexta (L.)	Tobacco Hornworm	Sphingidae	USA, C. & S. America	Larvae defoliate
Lasioderma serricorne (F.)	Tobacco Beetle	Anobiidae	Pantropical	Attack dried leaves

MINOR PESTS

Gryllus spp.	Crickets	Gryllidae	E. Africa	}
Atractomorpha crenula F.	Grasshopper	Acrididae	Malaysia	} Defoliate; destroy seedlings
Myzus persicae (Sulz.)	Peach Aphid	Aphididae	Cosmopolitan Europe, N. America	} Infest foliage; suck sap; virus vectors
Myzus ascalonicus Don.	Shallot Aphid	Aphididae		}
Aphis gossypii Glov.	Cotton Aphid	Aphididae	S.E. Asia	}
Aulacorthum solani (Malt.)	Potato Aphid	Aphididae	Cosmopolitan	}
Rhopalosiphum	Corn Leaf Aphid	Aphididae	Cosmopolitan	}
Empoasca spp.	Leafhoppers	Cicadellidae	S.E. Asia	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	S.E. Asia	Infest foliage
Planococcus citri Risso	Citrus (Root) Mealybug	Pseudococcidae	Widespread	Infest foliage
Saissetia coffeae (Wlk.)	Helmet Scale	Coccidae	Philippines	Infest stem
Cyrtopeltis spp.	Tomato Mirids	Miridae	Africa, India, S.E. Asia	} Sap-suckers; toxic saliva
Acanthocoris spp.	Coreid Bugs	Coreidae	Philippines	}
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	}
Frankliniella spp.	Flower Thrips	Thripidae	Cosmopolitan	Infest flowers & foliage
Lamprosema diamenalis Guen.	–	Pyralidae	Malaysia	Larvae eat leaves
Maruca testulalis (Geyer)	Mung Moth	Pyralidae	Widespread	Larvae eat leaves
Sylepta derogata (F.)	Cotton Leaf-roller	Pyralidae	S.E. Asia	Larvae roll leaves
Agrotis segetum (D. & S.)	Common Cutworm	Noctuidae	India, S.E. Asia	Larvae destroy seedlings
Tiracola plagiata (Wlk.)	Banana Fruit Caterpillar	Noctuidae	S.E. Asia	Larvae defoliate
Plusia spp.	Semi-loopers	Noctuidae	S.E. Asia	Larvae defoliate
Chrysodeixis chalcites (Esp.)	Cabbage Semi-looper	Noctuidae	Old World	Larvae defoliate
Heliothis assulta Gn.	Cape Gooseberry Budworm	Noctuidae	India, S.E. Asia	Larvae bore buds
Heliothis virescens (F.)	Tobacco Budworm	Noctuidae	N., C. & S. America	Larvae bore buds
Heliothis punctigera Wilgr.	Native Budworm	Noctuidae	Australia	Larvae defoliate

(continued)

Mythimna spp.	Rice Armyworms	Noctuidae	Pantropical	Larvae defoliate
Xestia c-nigrum (L.)	Spotted Cutworm	Noctuidae	Europe. Asia, N. America	Larvae are cutworms
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	S.E. Asia	Larvae defoliate
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa, S. Europe	Larvae defoliate
Spodoptera exigua (Hb.)	Lesser Armyworm	Noctuidae	Widespread in warmer regions	Larvae defoliate
Manduca quinquemaculata (Haw.)	Tomato Hornworm	Sphingidae	N., C. & S. America	Larvae defoliate
Agrius convolvuli (L.)	Convolvulus Hawk	Sphingidae	Old World	Larvae defoliate
Phthorimaea operculella (Zell.)	Potato Tuber Moth	Gelechiidae	Cosmopolitan	Larvae bore stem
Scrobipalpula absoluta Meyr.	Tomato Leafmine	Gelechiidae	S. America	Larvae mine leaves, etc.
Scrobipalpa heliopa (Lower)	Tobacco Stem Borer	Gelechiidae	India, S.E. Asia Africa	Larvae bore stem
Delia platura (Meign.)	Bean Seed Fly	Anthomyiidae	Cosmopolitan	Larvae bore sown seeds & seedlings
Solenopsis geminata (F.)	Fire Ant	Formicidae	India, S.E. Asia	Attack workers
Gonocephalum spp.	Dusty Brown Beetles	Tenebrionidae	Philippines, Africa	Adults damage stem
Epilachna spp.	Epilachna Beetles	Coccinellidae	Philippines, Asia, USA	Adults & larvae defoliate
Psylliodes spp.	Tobacco Flea Beetles	Chrysomelidae	Philippines	Adults hole leaves
Leptinotarsa decemlineata Say	Colorado Beetle	Chrysomelidae	Europe, USA, C. America	Adults & larvae defoliate
Epitrix hirtipennis (Melsh.)	Tobacco Flea Beetle	Chrysomelidae	USA (Florida)	Adults hole leaves
Oulema bilineata (Germ.)	Tobacco Leaf Beetle	Chrysomelidae	Africa, S. America	Adults eat leaves
Orthaulaca similis Ol.	Tobacco Leaf Beetle	Chrysomelidae	Philippines	Adults eat leaves
Agriotes spp.	Wireworms	Elateridae	Europe, Asia, USA	Larvae eat roots
Conoderus spp.	Tobacco Wireworms	Elateridae	USA	
Anomala spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Polyphagotarsonemus latus (Banks)	Yellow Mite	Tarsonemidae	S.E. Asia	Scarify leaves
Tetranychus cinnabarinus (Boisd.)	Carmine Mite	Tetranychidae	S.E. Asia	Scarify leaves

TOMATO (*Lycopersicum esculentum* – Solanaceae)

Tomato originated in S. America in the Peru/Ecuador region, and was taken to the Philippines and Malaya by 1650. For some time it has been cultivated in the temperate regions of America and Europe, but it was not cultivated in the tropics until the 20th century, but now is grown very widely throughout the world. It can be grown in the open wherever there is more than three months of frost-free weather, but needs even rainfall and long sunny periods for best results. It can be grown at sea-level but usually does better at higher altitudes. It is a variable annual herb, 0.7–2 m high, and the fruit for which it is grown is a fleshy berry, red or yellow when ripe, containing vitamins A and C. The fruit is used as a vegetable, raw or cooked, made into soup, sauce, juice, ketchup, paste, puree, powder or may be canned; also used unripe in chutneys. The main production areas are in the USA, Mexico and Italy, but most tropical countries have a large local production and consumption, and most temperate countries produce quantities under glass or polythene covers for local fresh consumption.

MAJOR PESTS				
Brachytrupes membranaceus (Drury)	Tobacco Cricket	Gryllidae	Africa	Destroy seedlings
Brachytrupes portentosus Litch.	Large Brown Cricket	Gryllidae	S.E. Asia	Destroy seedlings
Bemisia tabaci (Genn.)	Tobacco Whitefly	Aleyrodidae	Cosmopolitan	Infest foliage; suck sap; virus vector
Cyrtopeltis tenuis Reut.	Tomato Mirid	Miridae	Philippines, Africa	Sap-sucker; toxic saliva
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	Fruit spotted by feeding scars
Heliocoverpa armigera (Hub.)	Old World Bollworm (Tomato Fruitworm)	Noctuidae	Cosmopolitan in Old World	Larvae bore fruits
Heliocoverpa zea Boddie	Cotton Bollworm	Noctuidae	N., C. & S. America	Larvae bore fruits
Thrips tabaci Lind.	Onion Thrips	Thripidae	Cosmopolitan	Infest foliage
Tetranychus urticae (Koch)	Temperate Red Spider Mite	Tetranychidae	Europe, N. America	Scarify foliage
MINOR PESTS				
Phymateus aegrotus Gerst.	–	Acrididae	Africa	Defoliate
Grylloptalpa africana (Pal.)	African Mole Cricket	Gryllotalpidae	S.E. Asia	Eat roots
Aulacorthum solani (Kalt.)	Glasshouse/Potato Aphid	Aphididae	Europe, USA	Infest foliage; virus vector
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Cosmopolitan	Infest foliage; virus vector
Trialeurodes vaporariorum (Westw.)	Glasshouse Whitefly	Aleyrodidae	Europe, Ethiopia	Infest foliage; virus vector
Myzus persicae (Sulz.)	Green Peach Aphid	Aphididae	Cosmopolitan	Sap-sucker; virus vector
Empoasca spp.	Green Leafhoppers	Cicadellidae	S.E. Asia	Sap-sucker; infest foliage
Zygina pallidifrons	Glasshouse Leafhopper	Cicadellidae	Europe	Infest foliage
Ferrisia virgata (Ckll.)	Striped Mealybug	Pseudococcidae	Pantropical	Infest foliage
Pinnaspis minor Mask.	Armoured Scale	Diaspididae	Malaysia	Infest foliage
Anthocoris spp.	Coreid Bugs	Coreidae	Philippines	Sap-suckers; toxic saliva
Frankliniella spp.	Flower Thrips	Thripidae	Africa, USA, S. America	Infest flowers & leaves
Contarinia lycopersici Felt	Tomato Flower Midge	Cecidomyiidae	C & S America	Larvae destroy flowers
Dacus spp.	Fruit Flies	Tephritidae	Malaysia, Philippines	Larvae in fruit
Drosophila spp.	Vinegar Flies	Drosophilidae	Cosmopolitan	Attack ripe fruits
Liriomyza bryoniae (Kalt.)	Tomato Leaf Miner	Agromyzidae	Europe, N. Africa, USSR	Larvae mine leaves
Liriomyza spp.	Vegetables/Miner	Agromyzidae	USA, C & S America	
Keiferia lycopersicella	Tomato Pinworm	Gelechiidae	USA, W. Indies	Larvae mine leaves, bore stems & fruits
Phthorimaea operculella (Zeller)	Potato Tuber Moth	Gelechiidae	Cosmopolitan	
Scrobipalpula absoluta Meyr.	Tomato Leaf Miner	Gelechiidae	S. America	
Leucinodes orbonalis Guen.	Eggplant Boring Caterpillar	Pyralidae	Africa, India, S.E. Asia	Larvae bore fruit
Sceliodes laisalis (Wlk.)	–	Pyralidae	Africa	Larvae eat foliage
Lacanobia oleracea (L.)	Tomato Moth	Noctuidae	Europe	Larvae bore fruits

(continued)

Agrotis ipsilon Roth.	Black Cutworm	Noctuidae	S.E. Asia	Larvae are cutworms
Heliothis virescens (F.)	Tobacco Budworm	Noctuidae	N., C. & S. America	Larvae bore fruits
Heliothis assulta Gn.	Cape Gooseberry Budworm	Noctuidae	India, S.E. Asia Australasia, Africa	Larvae bore fruits
Heliothis punctigera	Native Budworm		Australia	
Othreis fullonia (Cl.)	Fruit-piercing Moth	Noctuidae	Old World tropics	Adults pierce fruits
Mythimna separata (Wlk.)	Rice Ear-cutting Caterpillar	Noctuidae	S.E. Asia	Larvae defoliate
Spodoptera litura (F.)	Rice Cutworm	Noctuidae	S.E. Asia	Larvae defoliate
Xestia c-nigrum (L.)	Spotted Cutworm	Noctuidae	Europe, Asia, N. America	Larvae are cutworms
Spodoptera littoralis (Boisd.)	Cotton Leafworm	Noctuidae	Africa, S. Europe	Larvae defoliate
Spodoptera exigua (Hb.)	Lesser Armyworm	Noctuidae	Widespread in warmer regions	Larvae defoliate
Chrysodeixis chalcites (Esp.)	Cabbage Semi-looper	Noctuidae	Old World	Larvae defoliate
Plusia spp.	Semi-loopers	Noctuidae	Cosmopolitan	
Anomis flava (F.)	Cotton Semi-looper	Noctuidae	Old World tropics	Larvae defoliate
Manduca quinquemaculata (Haw.)	Tomato Hornworm	Sphingidae	USA, C. & S. America	Larvae defoliate
Manduca sexta (L.)	Tobacco Hornworm	Sphingidae	USA, C. & S. America	
Acherontia atropos (L.)	Death's Head Hawk Moth	Sphingidae	Africa	Larvae defoliate
Agrius convolvuli (L.)	Sweet Potato Hawk Moth	Sphingidae	Cosmopolitan in Old World	Larvae defoliate
Leucopholis irrorata (Chevr.)	White Grub	Scarabaeidae	Philippines	Larvae eat roots
Anomala spp.	White Grubs	Scarabaeidae	Philippines	Larvae eat roots
Epilachna spp.	Epilachna Beetles	Coccinellidae	S.E. Asia	Adults & larvae defoliate
Leptinotarsa decemlineata (Say)	Colorado Beetle	Chrysomelidae	Europe (not UK), N. & C. America	Adults & larvae defoliate
Psylliodes spp.	Tobacco Flea Beetles	Chrysomelidae	Philippines	Adults hole leaves
Agriotes spp.	Wireworms	Elateridae	Europe	Larvae eat roots
Epicauta albovittata (Gestro)	Striped Blister Beetle	Meloidae	Africa	Adults eat flowers
Polyphagotarsonemus latus (Banks)	Yellow Tea Mite	Tarsonemidae	Cosmopolitan	Scarify leaves & fruits
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	Pantropical	Scarify leaves & fruits; web foliage
Tetranychus spp.	Red Spider Mites	Tetranychidae	Cosmopolitan	
Aculus lycopersici (Massee)	Tomato Russet Mite	Eriophyidae	Cosmopolitan	Scarity foliage
Eriophyes lycopersici (Wolf.)	Tomato Gall Mite	Eriophyidae	Pantropical	Erinia on foliage

TURMERIC (*Curcuma domestica* – Zingiberaceae) (= *C. longa*)

A rhizomatous herb, native to the tropical rain forests of India, cultivated for its tubers which yield a natural reddish dye, sometimes yellowish. It is an important spice amongst the rice-eating peoples of India, S.E. Asia, and Indonesia and it is indispensible in the preparation of curry powder; it gives the musky flavour and yellow colour to curries. Most curry powders contain about 24% turmeric powder, and this is the main present-day use for this plant. As a dye for cloth it was important until the discovery of the aniline dyes, but it is still used in India for this purpose, and in addition it has quite strong religious associations in that country.

MAJOR PESTS				
Dichocrocis punctiferalis Guen.	Castor Capsule Borer	Pyralidae	India	Larvae bore shoots & fruits
MINOR PESTS				
Aspidiella hartii Ckll.	Yam (Turmeric) Scale	Diaspididae	India, W. Africa, W. Indies	Encrust foliage & rhizomes
Stephanitis typicus Dist.	Banana Lace Bug	Tingidae	India	Sap-sucker; toxic saliva
Anaphothrips sudanensis Trybom	Wheat (Leaf) Thrips	Thripidae	India	Infest foliage
Panchaetothrips indicus Bagn.	Turmeric (Thrips)	Thripidae	India	Leaves wither
Udaspes folus Cr.	Skipper Butterfly	Hesperiidae	India	Larvae roll leaves
Diacrisia obliqua Wlk.	Tiger Moth	Arctiidae	India	Larvae defoliate

VANILLA (*Vanilla fragrans* – Orchidaceae) (= *V. planifolia*)

This important and popular flavouring material and spice comes from the fruits of a climbing orchid, native to the hot humid rain forests of tropical America. The fruits are harvested when fully grown but still unripe, and then they are fermented and cured; they are called vanilla beans. Vanilla extract is made by macerating the cured beans in alcohol; it is used mostly to flavour icecream, chocolate, beverages, cakes, puddings, and other confectionery. When cultivated, in hot wet tropical regions, the vine can be trained to grow up poles or else tree trunks; island climates are often the most suitable for vanilla production, but in general it is grown throughout the hot wet tropics.

MAJOR PESTS

MINOR PESTS

Mertilanidea fasciata Ghauri	Capsid Bug	Miridae	Papua NG	Sap-sucker; toxic saliva
Agraulis vanillae (L.)	Vanilla Butterfly	Nymphalidae	Colombia, Hawaii	Larvae eat leaves & fruits
Saula ferruginea Gerst.	–	?	India	Adults eat ventral leaf lamina
Amsacta transiens Wlk.	Woolly Bear	Arctiidae	Malaya	Larvae eat foliage

WALNUT (*Juglans regia* – Juglandaceae) (= English Walnut)

Despite its name this is a native of Iran and is now extensively cultivated in Europe (particularly France), China, N. India, other parts of Asia and also the USA. The trees are often used in an additional capacity as ornamentals for they are large (up to 20 m in height), and with a pleasing regular shape. The kernels are characteristically furrowed and are easily freed from the pericarp; they represent the cotyledons of the seed, no endosperm being present. The kernels are eaten raw, or pickled, used in cakes and confectionery, and also an oil can be extracted which is excellent for table use. *J. nigra* is the Black Walnut of the eastern deciduous forest region of the USA, but the shell is so hard that its use is more or less limited to the confectionery industry. *J. cinerea* is the Butternut of eastern USA and Canada, with a higher fat content than walnuts, and is used mainly for confectionery.

MAJOR PESTS				
Paramyelois transitella wlk.	Navel orange-worm	Pyralidae	USA (California)	Larvae bore fruits
Batocera horsfieldi Hope	Longhorn Beetle	Cerambycidae	India	Larvae bore trunk
MINOR PESTS				
Arytania fasciata Laing	Walnut Psylla	Psyllidae	India	Nymphs gall leaves
Aphis pomi de Geer	Apple Aphid	Aphididae	India	Adults & nymphs infest foliage, suck sap & make leaves curl
Callipterus juglandis Goeze	Walnut Aphid	Aphididae	Europe, India	
Chromaphis juglandicola (Kltb.)	Walnut Aphid	Aphididae	Europe, India, USA	
Parthenolecanium corni (Bch.)	Plum Scale	Coccidae	Europe, W. Asia	Infest foliage
Quadraspidiotus perniciosus (Comst.)	San José Scale	Diaspididae	India	Infest foliage
Aspidiotus juglansregiae Comst.	Walnut Scale	Diaspididae	USA	Infest foliage
Icerya purchasi Mask.	Cottony Cushion Scale	Margarodidae	India	Infest foliage
Pseudococcus maritimus (Ehrh.)	Grape Mealybug	Pseudococcidae	Widespread	Infest foliage
Cydia pomonella (L.)	Codling Moth	Tortricidae	Europe	Larvae bore fruits
Cydia funebrana (Treit.)	Red Plum Maggot	Tortricidae	Europe, Asia	Larvae bore fruits
Zeuzera spp.	Leopard Moths	Cossidae	Europe, India	Larvae bore branch
Datana integerrima G. & R.	Walnut Caterpillar	Notodontidae	USA	Larvae defoliate
Cressonia juglandis (J.E. Smith)	Walnut Sphinx	Sphingidae	USA	Larvae defoliate
Arctias selene (Hb.)	Moon Moth	Saturniidae	India	Larvae eat leaves
Phalera bucephala L.	Buff-tip Moth	Noctuidae	Europe	Larvae defoliate
Malacosoma indica Wlk.	Tent Caterpillar	Lasiocampidae	India	Larvae defoliate
Rhagoletis completa Cresson	Walnut Husk Fly	Tephritidae	USA	Larvae bore fruit husk
Holotrichia longipennis (Blanch.)	Cockchafer	Scarabaeidae	India	Larvae eat roots; adults eat leaves
Anomala spp.	Flower Beetles	Scarabaeidae	India	Adults eat leaves
Mimela pusilla Hope	Flower Beetle	Scarabaeidae	India	Adults eat leaves
Dorysthenus hugelii Redt.	Root Borer	Scarabaeidae	India	Larvae eat roots of young trees; adults eat leaves
Hispa dama Chap.	Hispid Beetle	Chrysomelidae	India	Larvae mine leaves; adults eat leaves
Altica cerulescens (Baly)	Flea Beetle	Chrysomelidae	India	Adults & larvae eat leaves
Monolepta erythrocephala Baly	Leaf Beetle	Chrysomelidae	India	Defoliate
Aeolesthes holoserica F.	Cherry Stem Borer	Cerambycidae	Pakistan, India	Larvae bore trunk & branches
Aeolesthes sarta Solsky	Quetta Borer	Cerambycidae	Pakistan, India	Larvae bore trunk & branches
Batocera rufomaculata (de Geer)	Red-spotted Longhorn	Cerambycidae	India	Larvae bore trunk
Alcidodes porrectirostris Mshll.	Walnut Weevil	Curculionidae	India	Larvae bore fruits
Myllocerus viridianus F.	Grey Weevil	Curculionidae	India	Adults eat leaves
Diapus pusillimus Chapuis	Walnut Pinhole Borer	Scolytidae	Australia	Adults bore trunk & branches
Scolytus juglandis	Walnut Pinhole Borer	Scolytidae	India	Adults bore branches
Aceria erinea (Nal.)	Walnut Blister Mite	Eriophyidae	Europe, USA, Australia	Erinea on leaves

WATERCRESS (*Nasturtium officinale* – Cruciferеae)

This is regarded as one of the minor herbage vegetables, grown widely but only for immediate local consumption. It occurs in the wild state in the UK and S. Europe, and is now introduced into many parts of the world. The plant is an aquatic perennial herb, and the tips of the leafy stems are used as salad, or it may be cooked as a vegetable. It grows best in clear running shallow water; the distal parts of the plant usually protrude from the water, and flowers are aerial.

MAJOR PESTS				
Plutella xylostella L.	Diamond-back Moth	Yponomeutidae	Malaysia	Larvae eat leaves
MINOR PESTS				
Myzus persicae (Sulz.)	Green Peach Aphid	Aphidiae	S. China	Adults & nymphs infest aerial foliage; suck sap
Lipaphis erysimi (Kalt.)	Turnip Aphid	Aphididae	S. China	
Rhopalosiphum rufiabdominalis (Sasaki)	Rice Root Aphid	Aphididae	S. China	
Phaedon aeruginosus Suff.	Watercress Leaf Beetle	Chrysomelidae	USA	Adults eat leaves

WHEAT (*Triticum sativum* – Gramineae) (including Barley and Oats)

Wheat is the chief cereal of temperate regions, and is the most widely grown cereal. As a crop it is of great antiquity, and its native home uncertain, although it is thought to be somewhere in C. or S.W. Asia. It was introduced into the New World in 1529 by the Spaniards who took it to Mexico. In the tropics this is not an important crop, but it is grown ever increasingly in the higher and cooler parts of some tropical countries (e.g. Kenya, India). In general, in the tropics, Wheat and Barley do not have a comparable pest spectrum to that which can cause considerable concern in most temperate countries. In temperate regions there are important differences between the pest spectra of Wheat, Barley, Oats and Rye.

MAJOR PESTS

Homorocoryphus nitidulus Wlk.	Edible Grasshopper	Tettigoniidae	E. Africa	Defoliate
Diuraphis noxius	Russian Wheat Aphid	Aphididae	Asia	Infest foliage; virus vectors
Schizaphis graminum Rond.	Wheat Aphid	Aphididae	Africa, Asia, USA, S. America	
Delia arambourgi Seguy	Barley Fly	Anthomyiidae	Africa	Destroy seedlings
Delia coarctata (Fall.)	Wheat Bulb Fly	Anthomyiidae	Europe, Asia	Larvae bore stems of seedlings
Oscinella frit (L.)	Frit Fly	Chloropidae	Europe	Larvae gall stems
Mayetiola destructor (Say)	Hessian Fly	Cecidomyiidae	Europe, N. America	Larvae gall stems
Sesamia inferens (Wlk.)	Purple Stem Borer	Noctuidae	India, Pakistan, China, S.E. Asia, Japan, Indonesia, Philippines	Larvae bore stems
Nematocerus spp.	Nematocerus Weevils	Curculionidae	E. Africa	Adults eat leaves; larvae eat roots
Heteronychus consimilis Kolbe	Black Wheat Beetle	Scarabaeidae	E. Africa	Adults eat stem; larvae eat roots
Epilachna similis (Thun.)	Epilachna Beetle	Coccinellidae	Africa	Adults & larvae eat leaves

MINOR PESTS

Rhopalosiphum maidis (Fitch)	Corn Leaf Aphid	Aphididae	Cosmopolitan	Adults & nymphs infest foliage; sap-suckers & virus vectors
Rhopalosiphum padi (L.)	Bird-cherry Aphid	Aphididae	Europe	
Rhopalosiphum insertum (Wlk.)	Apple–Grass Aphid	Aphididae	Europe	
Macrosiphum fragariae Wlk.	Blackberry Aphid	Aphididae	Cosmopolitan	
Macrosiphum avenae (F.)	Grain Leaf Aphid	Aphididae	Europe	
Metopolophium dirhodum (Wlk.)	Rose–Grain Aphid	Aphididae	Europe	
Metopolophium festucae (Theob.)	Fescue Aphid	Aphididae	Europe	
Melanaphis sacchari (Zhnt.)	Sugarcane Aphid	Aphididae	Pantropical	
Laodelphax striatella (Fall.)	Small Brown Leafhopper	Delphacidae	Europe, Asia, China, Japan, S.E. Asia	Sap-sucker; virus vector
Delphacodes pellucida (F.)	Cereal Leafhopper	Delphacidae	Europe	Sap-sucker
Eurygaster spp.	Wheat Shield Bugs	Pentatomidae	Europe, W. Asia	Sap-suckers
Blissus leucopterus (Say)	Chinch Bug	Lygaeidae	N. & S. America	Sap-sucker
Pyrilla perpusilla Wlk.	Indian Sugarcane Leafhopper	Lophopidae	India	Sap-sucker
Crambus spp.	Grass Moths	Crambidae	Europe, USA	Larvae bore stems
Marasmia trapezalis (Gn.)	Maize Webworm	Pyralidae	Africa, India, S.E. Asia, Australasia, C. & S. America	Larvae eat leaves
Sitotroga cereallela (Ol.)	Angoumois Grain Moth	Gelechiidae	Widespread	Larvae eat grains
Hepialus spp.	Swift Moths	Hepialidae	Europe	Larvae eat roots
Spodoptera frugiperda (J.E. Smith)	Fall Armyworm	Noctuidae	N., C. & S. America	Larvae defoliate

(continued)

Luperina testacea (Schiff.)	Flounced Rustic Moth	Noctuidae	Europe	Larvae bore stems
Mesapamea secalis (L.)	Common Rustic Moth	Noctuidae	Europe	
Mythimna spp.	Cereal Army-worms	Noctuidae	Cosmopolitan	Larvae defoliate
Hydrellia griseola (Fall.)	Cereal Leaf Miner	Ephydridae	Europe, Asia, N. Africa, USA, S. America	Larvae mine leaves
Atherigona oryzae Mall.	Rice Shoot Fly	Muscidae	S. & E. Asia	Larvae bore young shoot
Delia platura (Meign.)	Bean Seed Fly	Anthomyiidae	Cosmopolitan	Larvae eat germinating seed
Phorbia genitalis Tiens.	Late Wheat Shoot Fly	Anthomyiidae	Europe	Larvae bore shoots
Agromyza ambigua Fall.	Cereal Leaf Miner	Agromyzidae	Europe, USA, Canada	Larvae mine leaves
Chlorops pumilionis (Bjerk.)	Gout Fly	Chloropidae	Europe	Larvae gall shoots
Geomyza spp.	Grass Flies	Geomyzidae	Europe	Larvae bore shoots
Opomyza spp.	Grass Flies	Opomyzidae	Europe	Larvae bore shoots
Bibio marci (L.)	St. Mark's Fly	Bibionidae	Europe	Larvae eat roots
Haplodiplosis equestris (Wagn.)	Saddle Gall Midge	Cecidomyiidae	Europe	Larvae gall stems
Mayetiola spp.	'Flax' Flies	Cecidomyiidae	Cosmopolitan	Larvae gall stems
Mayetiola avenae (March.)	Oat Stem Midge	Cecidomyiidae	Europe	Larvae gall stems
Contarinia tricici (Kirby)	Yellow Wheat Blossom Midge	Cecidomyiidae	Europe	Larvae infest flower head
Sitodiplosis mossellana (Gehin)	Orange Wheat Blossom Midge	Cecidomyiidae	Europe	Larvae infest flower head
Limothrips cerealium Hal.	Grain Thrips	Thripidae	Europe	Infest flowers
Aptinothrips spp.	Grass Thrips	Thripidae	Europe	Infest flowers
Stenothrips graminum Uzel	Oat Thrips	Thripidae	Europe	Infest flowers
Thrips nigropilosus Uzel	Chrysanthemum Thrips	Thripidae	Europe, E. Africa, N. America	Infest flowers
Tipula spp.	Leatherjackets	Tipulidae	Europe	Larvae eat roots
Nephrotoma spp.	Leatherjackets	Tipulidae	Europe	
Cephus pygmaeus (L.)	Wheat Stem Sawfly	Cephidae	Europe	Larvae gall stem
Dolerus spp.	Leaf Sawflies	Tenthredinidae	Europe	Larvae eat leaves
Agriotes spp.	Wireworms	Elateridae	Europe	Larvae eat roots
Athous spp.	Garden Wireworms	Elateridae	Europe	Larvae eat roots
Corymbites spp.	Upland Wireworms	Elateridae	Europe	Larvae eat roots
Helophorus nubilus F.	Wheat Shoot Beetle	Hydrophilidae	Europe	Larvae bite young shoots
Oulema melanopa (L.)	Cereal Leaf Beetle	Chrysomelidae	Europe, USA	Larvae mine leaves; adults eat leaves
Phyllotreta vittula Redt.	Barley Flea Beetle	Chrysomelidae	Europe	Adults eat leaves
Chaetocnema hortensis (Geoff.)	Cereal Flea Beetle	Chrysomelidae	Europe	Adults eat leaves
Crepidodera ferruginea (Scop.)	Wheat Flea Beetle	Chrysomelidae	Europe	Adults eat leaves
Melolontha melolontha (L.)	Cockchafer	Scarabaeidae	Europe	Larvae eat roots
Amphimallon solstitialis (L.)	Summer Chafer	Scarabaeidae	Europe	Larvae eat roots
Serica brunnea (L.)	Brown Chafer	Scarabaeidae	Europe	Larvae eat roots
Schizonycha spp.	Chafer Grubs	Scarabaeidae	Europe	Larvae eat roots
Gonocephalum simplex (F.)	Dusty Brown Beetle	Tenebrionidae	Africa	Adult damages stem; larvae eat roots
Tanymecus dilaticollis Gylh.	Southern Grey Weevil	Curculionidae	E. Europe	Damage foliage
Stenotarsonemus spirifex (March.)	Oat Spiral Mite	Tarsonemidae	Europe	Damage flowers

YAM (*Dioscorea esculenta* – Dioscoreaceae) & *D.* spp.

Yams are native to the Old World tropics, with wild species being found in parts of both Africa and Asia. Now the crop is really only of importance in W. Africa and parts of Vietnam, Cambodia and Laos. It needs a high tropical rainfall. The yam itself is a swollen tuber of a climbing vine, and contains little food except starch. The tubers can be stored either in the ground or on racks in farm stores. About a dozen different species of yams are known in addition to the common one (*D. esculenta*).

MAJOR PESTS				
Prionoryctes caniculus Arr.	Yam Beetle	Scarabaeidae	Africa	Larvae bore tubers
Heteroligus meles (Billb.)	Greater Yam Beetle	Scarabaeidae	W. Africa	Adults & larvae bore tubers
MINOR PESTS				
Gymnogryllus lucens (W.)	Cricket	Gryllidae	Nigeria	Damage roots & tubers
Aphis gossypii Glov.	Cotton Aphid	Aphididae	Nigeria	Infest foliage; virus vector
Geococcus colleae Green	–	Pseudococcidae	Pantropical	Infest foliage & roots
Planococcus kenyae (Le Pelley)	Kenya Mealybug	Pseudococcidae	E. & W. Africa	Infest foliage & roots
Planococcus citri (Risso)	Citrus (Root) Mealybug	Pseudococcidae	S.E. Asia	Infest foliage & roots
Planococcus dioscoreae Williams	Yam Mealybug	Pseudococcidae	Papua N.G.	Infest foliage & roots
Ptyelus grossus F.	Spittle Bug	Cercopidae	Africa	Larvae infest foliage
Aspidiella hartii (Ckll.)	Yam Scale	Diaspididae	India, W. Indies	Infest foliage
Aspidiotus destructor Sign.	Coconut Scale	Diaspididae	S.E. Asia	Infest foliage
Quadraspidiotus perniciosus (Comst.)	San José Scale	Diaspididae	S.E. Asia	Infest foliage
Helopeltis sp.	Mosquito Bug	Miridae	Malaysia	Sap-sucker; toxic saliva
Leptoglossus australis (F.)	Leaf-footed Plant Bug	Coreidae	S.E. Asia	Sap-sucker; toxic saliva
Tagiades litigiosa	Yam Skipper (Water Snow Flat)	Hesperiidae	S.E. Asia	Larvae roll leaf edges
Senoclidia purpurata (F. Sm.)	Sawfly	Tenthredinidae	Papua N.G.	Gregarious larvae eat leaves
Schizonycha sp.	Chafer Grub	Scarabaeidae	Africa	Larvae eat roots
Heteronychus spp.	Black Cereal Beetles	Scarabaeidae	Africa	Larvae eat roots
Heteroligus appius (Burm.)	Lesser Yam Beetle	Scarabaeidae	W. Africa	Larvae bore tubers
Prionoryctes rufopiceus Arr.	–	Scarabaeidae	W. Africa	Larvae bore tubers
Lepidiota reichei (J. Thom.)	–	Scarabaeidae	W. Africa	Larvae bore tubers
Crioceris livida Dalm.	Leaf Beetle	Chrysomelidae	W. Africa	Adults & larvae eat leaves
Apomecyna parumpunctata Chrvr.	Longhorn Beetle	Cerambycidae	Nigeria	Larvae bore stems
Palaeopus dioscorae Pierce	Yam Weevil	Curculionidae	Jamaica, Cuba	Larvae bore tubers

PEST OF SEEDLINGS AND GENERAL PESTS

Many of the pests already referred to are particularly damaging to seedlings and young crop plants, and many are also polyphagous and recorded from many different crops, both as major and minor pests. In general soil-dwelling pests are not host specific but will attack (eat) the roots and underground stems of almost anything rather small, and not too woody, growing in that soil. Similarly, some general sap-suckers (Hemiptera; Tetranychidae) and leaf-eaters (Acrididae; Noctuidae; Curculionidae) do not appear to be particularly selective as to host. Some of these general pests, such as locusts, are more restricted geographically than by host preferences.

MAJOR PESTS				
Sminthurus viridis (L.)	Lucerne 'Flea'	Sminthuridae	Europe	Damage seedlings, especially ones with soft stems
Bourletiella hortensis (Fitch)	Garden Springtail	Sminthuridae	Europe, USA	
Onychiurus spp.	Springtails	Onychiuridae	Cosmopolitan	
Patanga succincta (L.)	Bombay Locust	Acrididae	India, S.E. Asia, China	General defoliator
Zonocerus spp.	Variegated Grasshoppers	Acrididae	Africa	General defoliators of Dicots.
Chortoicetes terminifera (Wlk.)	Australian Plague Locust	Acrididae	Australia	General defoliator
Consunata virens	–	Acrididae	Trinidad	Defoliator of Dicots.
Dociostaurus maroccanus (Thnb.)	Mediterranean Locust	Acrididae	Med.	General defoliator
Schistocerca gregaria (Forsk.)	Desert Locust	Acrididae	Africa to India	General defoliator
Nomadacris septemfasciata (Serv.)	Red Locust	Acrididae	C. & Southern Africa	General defoliator
Locusta migratoria migratoria	Asiatic Migratory Locust	Acrididae	C. Asia	General defoliator
Locusta m. migratorioides (R. & F.)	African Migratory Locust	Acrididae	Tropical Africa	General defoliator
Locusta m. maniliensis (Meyr.)	Oriental Migratory Locust	Acrididae	S.E. Asia, Philippines, Australia, Borneo, China	General defoliator
Gastrimargus spp.	Grasshoppers	Acrididae	S.E. Asia, India, Africa	General defoliator
Gryllotalpa spp.	Mole Crickets	Gryllotalpidae	Cosmopolitan	Soil feeder
Acheta spp.	Field Crickets	Gryllidae	Cosmopolitan	Nest in soil; seedling pests; eat roots of older plants
Brachytrupes membranaceus (Drury)	Tobacco Cricket	Gryllidae	Africa	
Brachytrupes portentosus Licht.	Large Brown Cricket	Gryllidae	India, S.E. Asia, China	
Macrotermes spp.	Mound-building Termites	Termitidae	Old World tropics	Remove bark & foliage for fungus gardens
Odontotermes spp.	Scavenging Termites	Termitidae	Pantropical	Collect vegetable material
Aphis spp.	Aphids	Aphididae	Cosmopolitan	
Coccus spp.	Scale Insects	Coccidae	Pantropical	Polyphagous sap-suckers
Nezara viridula (L.)	Green Stink Bug	Pentatomidae	Cosmopolitan	
Lygocoris pabulinus (L.)	Common Green Capsid	Miridae	Europe	Polyphagous sap-suckers; toxic saliva
Lygus rugulipennis Popp.	Tarnished Plant Bug	Miridae	Europe	
Helopeltis spp.	Mosquito Bugs	Miridae	Pantropical	
Forficula auricularia L.	Common Earwig	Forficulidae	Cosmopolitan	Pest of small seedlings only
Hepialus spp.	Swift Moths	Hepialidae	Cosmopolitan in temperate regions	Larvae in soil eat plant roots
Agrotis spp.				
Euoxa spp.	Cutworms	Noctuidae	Cosmopolitan	Larvae are cutworms in soil
Spodoptera spp.				
Noctua pronuba (L.)	Large Yellow Underwing	Noctuidae	Europe, Asia,	Larvae are cutworms
Heliothis spp.	Leafworms, etc.	Noctuidae	Cosmopolitan	Larvae polyphagous leaf-eaters
Spodoptera spp.				
Spodoptera spp.	Armyworms	Noctuidae	Pantropical	Larvae polyphagous leaf-eaters; gregarious habits
Mythimna spp.				

(continued)

Plusia spp.	Semi-loopers	Noctuidae	Cosmopolitan	Larvae polyphagous defoliators
Cnephasia spp.	Polyphagous Leaf Tiers	Tortricidae	Europe, Asia N. America	Larvae polyphagous leaf eaters
Delia platura (Meign.)	Bean Seed Fly	Anthomyiidae	Cosmopolitan	Larvae eat germinating seeds & seedlings
Tipula spp.	Leatherjackets (Common Crane Flies)	Tipulidae	Europe, Asia	Larvae polyphagous soil pests; eat roots & seedlings
Nephrotoma spp.	Spotted Crane Flies	Tipulidae	Europe, USA, Canada	
Solenopsis geminata (F.)	Fire Ant	Formicidae	Pantropical	Biting ant; nests in plantations & attacks farm workers
Atta spp.	Leaf-cutting Ants	Formicidae	C. & S. America	Adults are polyphagous defoliators
Acromyrmex spp.	Leaf-cutting Ants	Formicidae	C. & S. America	
Vespa spp.	Common Wasps	Vespidae	Cosmopolitan	Adults pierce ripe fruits
Agriotes spp.	Wireworms	Elateridae	Europe, etc.	Larvae polyphagous soil pests
Popillia japonica Newm.	Japanese Beetle	Scarabaeidae (Rutelinae)	E. Asia, N. Europe, USA	Adults defoliate
Anomala spp.	Flower Beetles (White Grubs)	Scarabaeidae	Cosmopolitan	Larvae in soil eat plant roots; adults eat leaves
Adoretus spp.	Flower Beetles	Scarabaeidae	Pantropical	
Cetonia spp.	Rose Chafers (White Grubs)	Scarabaeidae (Cetoni-dae)	Cosmopolitan	Larvae in soil eat roots; adults feed on nectar & ripe fruits only
Protaetia spp.	Rose Chafers	Scarabaeidae	Pantropical	
Melolontha spp.			Cosmopolitan	
Holotrichia spp.	Cockchafers (Chafers) (Chafer Grubs) (White Grubs)	Scarabaeidae (Melolon-thinae)		Larvae in soil; polyphagous pests; adults eat leaves, & unripe fruits sometimes
Serica spp.			Cosmopolitan	
Phyllophaga spp.				
Leucopholis spp.				
Schizonycha spp.				
Otiorhynchus spp.	Clay-coloured Weevils	Curculionidae	Europe	Larvae eat roots in soil; adults eat leaf edges
Hypomeces squamosus (F.)	Gold-dust Weevil	Curculionidae	India, S.E. Asia, China	Adults eat leaves
Systates spp.	Systates Weevils	Curculionidae	Africa	Adults eat leaves
Myllocerus spp.	Grey Weevils	Curculionidae	India	Adults eat leaves
Tetranychus cinnabarinus (Boisd.)	Tropical Red Spider Mite	Tetranychidae	Pantropical	Adults & nymphs scarify foliage
Tetranychus urticae (Koch)	Temperate Red Spider Mite	Tetranychidae	Cosmopolitan in temperate countries	
Panonychus ulmi (Koch)	Fruit Tree Red Spider Mite	Tetranychidae	Cosmopolitan in temperate countries	

INSECT PESTS OF STORED PRODUCTS

The number of types of foodstuffs, plant and animal material stored, and the vast range of on-farm stores, barns, warehouses and godowns, is so great and varied that it is not feasible to make generalizations about either the stored products or the stores. But the range of pests encountered in the different parts of the world is much the same irrespective of the precise locality, and the pests do show certain definite preferences in relation to their choice of food; some species will only feed on pulses, others only on dried animal material, or grains, or flours. Some species are primary pests in that they can attack intact seeds and grains; the secondary pests are unable to do this and only feed on damaged grains. A few species are definitely tropical and some others equally temperate, so their distribution is not so wide as other species. Often the recognition and control of stored products pests does not come within the responsibility of the agricultural entomologist, but sometimes it does. See Hill, 2002.

Several Rodentia and birds can be major pests.

MAJOR PESTS				
Sitotroga cerealella (Ol.)	Angoumois Grain Moth	Gelechiidae	Widespread	Grains & foodstuffs
Ephestia cautella (Hb.)	Dried Currant Moth	Pyralidae	Widespread	Dried fruits
Ephestia elutella (Hb.)	Warehouse Moth	Pyralidae	Widespread	Dried fruits, cocoa beans, tobacco etc.
Lasioderma serricorne (F.)	Tobacco Beetle (Cigarette Beetle)	Anobiidae	Tropical	Dried tobacco, foodstuffs etc.
Tribolium castaneum (Herbst)	Red Flour Beetle	Tenebrionidae	Widespread	Flours & grain products
Oryzaephilus surinamensis (L.)	Saw-toothed Grain Beetle	Silvaniidae	Tropical	Secondary pests of foodstuffs
Oryzaephilus mercator (Fauvel)	Merchant Grain Beetle	Silvaniidae	Tropical	
Rhizopertha dominica (F.)	Lesser Grain Borer	Bostrychidae	Tropical	Grains bored, Cassava tubers
Prostephanus truncatus Hom.	Greater Grain Borer	Bostrychidae	S. America, Africa	
Acanthoscelides obtectus (Say)	Bean Bruchid	Bruchidae	Tropical	Pulses only
Callosobruchus maculatus (F.)	Spotted Cowpea Bruchid	Bruchidae	Tropical	Pulses only
Callosobruchus chinensis (L.)	Oriental Cowpea Bruchid	Bruchidae	Tropical	Pulses only
Caryedon serratus (Oliv.)	Groundnut Borer	Bruchidae	Tropical	Pulses, groundnuts
Dermestes lardarius L.	Larder Beetle	Dermestidae	Widespread	Dried animal matter
Dermestes maculatus Deg.	Hide Beetle	Dermestidae	Widespread	Dried animal matter
Trogoderma granarium Everts.	Khapra Beetle	Dermestidae	Tropical	Grains, groundnut
Sitophilus oryzae (L.)	Rice Weevil	Curculionidae	Widespread	Rice, maize, foodstuffs etc.
Sitophilus zeamais Motsch.	Maize Weevil	Curculionidae	Widespread	Maize, rice, foodstuffs etc.
Araecerus fasciculatus (Deg.)	Coffee Bean Weevil	Anthribidae	Tropical	Coffee beans, seeds etc.
MINOR PESTS				
Lepisma saccharina L.	'Silverfish'	Thysanura	Cosmopolitan	Scavenger; polyphagous
Periplaneta americana (L.)	American Cockroach	Blattidae	Cosmopolitan	Scavenger; polyphagous
Blatta orientalis L.	Oriental Cockroach	Blattidae	Temperate	Scavenger; polyphagous
Blatella germanica (L.)	German Cockroach	Blattidae	Cosmopolitan	Scavenger; polyphagous
Acheta domesticus (L.)	House Cricket	Gryllidae	Temperate	Scavenger; polyphagous
Nemapogon granella (L.)	Corn Moth	Tinaeidae	Cosmopolitan	Dried vegetable matter
Ephestia kuehniella (Zell.)	Mediterranean Flour Moth	Pyralidae	Sub-tropical	Flours mostly
Plodia interpunctella (Hub.)	Indian Meal Moth	Pyralidae	Tropical	Dried fruits, meals, flours etc.
Carpophilus hemipterus (L.)	Dried Fruit Beetle	Nitidulidae	Widespread	Dried fruits
Attagenus piceus Oliv.	Black Carpet Beetle	Dermestidae	Widespread	Dried animal matter
Ahasverus advena (Waltl.)	Foreign Grain Beetle	Silvanidae	Widespread	Fungus feeder
Necrobta rufipes (Deg.)	Copra Beetle	Cleridae	Tropical	Copra, oil seeds, dried meats
Typhaea stercorea (L.)	Hairy Fungus Beetle	Mycetophagidae	Widespread	Fungus feeder
Stegobium paniceum (L.)	Drug Store Beetle	Anobiidae	Temperate	Foodstuffs
Cryptolestes ferrugineas (Steph.)	Rust-red Grain Beetle	Cucujidae	Widespread	Grains
Ptinus spp.	Spider Beetles	Ptinidae	Tropical	Miscellaneous foodstuffs
Tenebrio molitor L.	Yellow Mealworm Beetle	Tenebrionidae	Widespread	Flours & foodstuffs
Tribolium confusum J. du V.	Confused Flour Beetle	Tenebrionidae	Widespread	Flours mostly
Tenebriodes mauritanicus (L.)	Cadelle	Tenebrionidae	Widespread	Miscellaneous foodstuffs
Sitophilus granarius (L.)	Grain Weevil	Curculionidae	Temperate	Wheat, other grains, foodstuff etc.
Acarus siro L.	Flour Mite	Acaridae	Widespread	Flours, meals etc.

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Appendix A Glossary of terms used in applied entomology and crop protection

Acaricide Material toxic to mites (Acarina).
Activator Chemical added to a pesticide to increase its toxicity.
Active ingredient (a.i.) Toxic component of a formulated pesticide.
Adherence The ability of a material to stick to a particular surface.
Adhesive (= Sticker) Material added to increase pesticide retention; different commercial preparations of methyl cellulose are available for this purpose.
Adjuvant A spray additive to improve either physical or chemical properties (*see also* Supplement, Sticker, Adhesive, Spreader, Wetter and Emulsifier).
Aedeagus The male intromittent organ, or penis.
Aerosol A dispersion of spray droplets of diameter 0.1–5.0μm; usually dispersed from a canister.
Aestivation Dormancy during a hot or dry season.
Agamic Parthenogenetic reproduction; without mating.
Agitator A mechanical device in the spray tank to ensure uniform distribution of toxicant and to prevent sedimentation.
Agroecology The study of ecology in relation to agricultural systems.
Allochthonous Not aboriginal; exotic; introduced; acquired from elsewhere (opp. autochthonous).
Allopatric Having separate and mutually exclusive areas of geographical distribution (opp. sympatric).
Anemophilous Plants which are pollinated by the wind.
Anionic surfactant Salt of an organic acid, the structure of which determines its surface activity.
Antibiosis The resistance of a plant to insect attack by having, for example, a thick cuticle, hairy leaves, toxic sap, etc.
Anti-feedant A chemical possessing the property of inhibiting the feeding of certain insect pests.
Anti-frothing agent Material added to prevent frothing of the liquid in the spray tank.
Approved product Proprietary brand of pesticide officially approved by the Ministry of Agriculture, Fisheries and Food, UK.
Antixenosis (= non-preference)
Arista A large bristle, located on the dorsal edge of the apical antennal segment in the Diptera.
Asymptote The point in the growth of a population at which numerical stability is reached.
Atomiser Device for breaking up a liquid stream into very fine droplets by a stream of air.
Atrophied Reduced in size; rudimentary; vestigial.
Attractant Material with an odour that attracts certain insects; lure. Several proprietory lures are manufactured.
Autecology The study of a single species.
Autochthonous Aboriginal; native; indigenous; formed where found (opp. allochthonous).
Autocide The control of a pest by the sterile-male technique.
Bait Foodstuff used for attracting pests; usually mixed with a poison to form a poison bait.
Band application Treatment of a band of soil in row-crops, usually covering plant rows, with either sprays or granules.
Biocide A general poison or toxicant.
Boom (spray) Horizontal (or vertical) light frame carrying several spray nozzles.
Brachypterous Having short wings that do not cover the abdomen.
Breaking The separation of the phases from emulsion.
Browsing The eating of foliage of bushes and trees.
Budworm Common name in the USA for various tortricid larvae.
Calling A virgin female moth releasing sex pheromones to attract males for the purpose of mating.
Carrier Material serving as diluent and vehicle for the active ingredients; usually in dusts.
Cationic surfactant Material in which surface activity is determined by the basic part of a compound.
Caterpillar Eruciform larva; larva of a moth, butterfly, or sawfly.
Chaetotaxy The arrangement and nomenclature of the bristles on the insect exoskeleton, both adults and larvae.
Chemosterilant Chemical used to render an insect sterile without killing it.
Chrysalis The pupa of a butterfly.
Climatograph A polygonal diagram resulting from plotting temperature means against relative humidity.
Clone A group of identical individuals propagated vegetatively from a single plant.
Coarctate pupa A pupa enclosed inside a hardened shell formed by the previous larval skin.
Cocoon A silken case inside which a pupa is formed.
Colloidal formulation Solution in which the particle size is less than 6μm in diameter, and the particles stay indefinitely dispersed.
Commensalism Two organisms living together and sharing food, both species usually benefiting from the association; a type of symbiosis.
Community The collection of different species and types of plants and animals, in their respective niches, within the habitat. 1. Closed: the habitat is completely colonized by plants; no areas of bare soil; strong competition for space. 2. Open: habitat is not completely colonized by plants; bare areas of soil; competition for space is thus reduced.
Compatibility The ability to mix different pesticides without physical or chemical interactions which would lead to reduction in biological efficiency or increase in phyto-toxicity.
Compressed Flattened from side to side.
Concentrated solution (c.s.) Commercial pesticide preparation before dilution for use.
Concentrate spraying Direct application of the pesticide concentrate without dilution.
Concentration Proportion of active ingredient in a pesticide preparation, before or after dilution.
Contact poison Material killing pests by contact action, presumably by absorption through the cuticle.
Control (noun) Untreated subjects used for comparison with those given a particular crop protection treatment.
Control (verb) To reduce damage or pest density to a level below the economic threshold. 1. Legislative: the use of legislation to control the importation and to prevent any spread of a pest within a country. 2. Physical: the use of mechanical (hand picking, etc.) and physical methods (heat, cold, radiation, etc.) of controlling pests.

3. Cultural: regular farm operations designed to destroy pests. 4. Chemical: the use of chemical pesticides as smokes, gas, dusts, and sprays to poison pests. 5. Biological: the use of natural predators, parasites and disease organisms to reduce pest populations. 6. Integrated: the very carefully reasoned use of several different methods of pest control in conjunction with each other to control pests with a minimum disturbance to the natural situation.

Cosmopolitan A species occurring very widely throughout the major regions of the world.

Costa A longitudinal wing vein, usually forming the anterior margin (leading edge).

Cover Proportion of the surface area of the target plant on which the pesticide has been deposited.

Crawlers The active first instar of a scale insect.

Cremaster A hooked, or spine-like process at the posterior end of the pupa, often used for attachment (Lepidoptera).

Crepuscular Animals that are active in the twilight, pre-dawn and at dusk in the evenings.

Crochets Hooked spines at the tips of the prolegs of lepidopterous larvae.

Crop hygiene (= Phytosanitation) The removal and destruction of heavily infested or diseased plants from a crop so that they do not form sources of reinfestation.

Cutworm Larva of certain Noctuidae that lives in the soil, emerging at night to eat foliage and stems; serious pests of many crops as seedlings, and root crops.

Deflocculating agent Material added to a spray suspension to delay sedimentation.

Defoliant Spray which induces premature leaf-fall.

Deposit (spray) Amount and pattern of spray or dust deposited per unit area of plant surface.

Deposit (dried) Amount and pattern of active ingredient deposited per unit area of plant surface.

Deposition velocity Velocity at which the spray impinges on the target.

Depressed Flattened dorso-ventrally.

Desiccant Chemical which kills vegetation by inducing excessiv water loss.

Diluent Component of spray or dust that reduces the concentration of the active ingredient, and may aid in mechanical application but does not directly affect toxicity.

Disinfect 1. To free from infection by destruction of the pest or pathogen established in or on plants or plant parts. 2. To kill or inactivate pests or pathogens present upon the surface of plants or plant parts, or in the immediate vicinity (e.g. in soil).

Dispersal Movement of individuals out of a population (emigration) or into a population (immigration).

Diurnal Active during the daytime.

Dormant Alive but not growing; buds with an unbroken cover of scales; quiescent; inactive; a resting stage.

Dose; dosage Quantity of pesticide applied per individual, or per unit area, or per unit volume, or per unit weight.

Drift Spray or dust carried by natural air currents beyond the target area.

Drop spectrum Distribution, by number or volume of drops, of spray into different droplet sizes.

Duster Equipment for applying pesticide dusts to a crop.

Ecdysis The moulting (shedding of the skin) of larval arthropods from one stage of development to another – the final moult leading to the formation of the puparium or chrysalis.

Ecesis (= Oikesis) The establishment of an organism in a new habitat; accidental dispersal and establishment in a new area.

Ecoclimate Climate within the plant (crop) community.

Ecology The study of all the living organisms in an area and their physical environment.

Economic damage The injury done to a crop which will justify the cost of artifical control measures.

Economic-injury level The lowest population density that will cause economic damage.

Economic pest A pest causing a crop loss of about 5–10%, according to definition.

Economic threshold The pest population level at which control measures should be started to prevent the pest population from reaching the economic-injury level.

Ecosystem The interacting system of the living organisms in an area and their physical environment.

Efficiency of a pest control measure The more or less fixed reduction of a pest population regardless of the number of pests involved.

Effectiveness of a pest control measure This is shown by the number of pests remaining after control treatment.

Elateriform larva A larva resembling a wireworm with a slender body, heavily sclerotinized, with short thoracic legs and only a few body bristles.

Elytron The thickened forewing of the Coleoptera.

Emergence 1. The adult insect leaving the last nymphal skin, or pupal case. 2. Germination of a seed and the appearance of the shoot.

Emigration The movement of individuals out of a population.

Emulsifiable concentrate (e.c.) Liquid formulation that when added to water will spontaneously disperse as fine droplets to form an emulsion (= Miscible oil).

Emulsifier Spray additive which permits formation of a stable suspension of oil droplets in aqueous solution, or of aqueous solution in oil.

Emulsion A stable dispersion of oil droplets in aqueous solution, or vice cersa.

Emulsion, Invert Suspension of aqueous solution in oil.

Encapsulation Or microencapsulation: the encapsulation of a pesticide in a non-volatile envelope of gelatin, usually of minute size, for delayed release.

Entomophagous An animal (or plant) which feeds upon insects.

Erinium A growth of hairs in dense patches on plant leaves resulting from the attack of certain Eriophyidae (Acarina).

Eruciform larva Caterpillar; a larva with a cylindrical body, well-developed head, and with both thoracic legs and some abdominal prolegs.

Exarate pupa A pupa in which the appendages are free and not glued to the insect body.

Exuvium The cast skin of arthropods after moulting.

Fecundity Capacity to produce offspring (reproduce); power of a species to multiply rapidly.

Filler Inert component of pesticide dust or granule formulation.

Flowability Property of flowing possessed by dusts, colloids, liquids, and some pastes.

Fluorescent tracer Fluorescent material added to a spray to aid the assessment of spray deposits on plants.

Formulation 1. Statement of nature and amount of all constituents of a pesticide concentrate. 2. Method of preparation of a pesticide concentrate.

Fossorial Modified for digging; in the habit of digging or burrowing.

Frass Wood fragments made by a wood-boring insect, usually mixed with the faeces.

Fumigant Pesticide exhibiting toxicity in the vapour phase.
Furrow application Placement of pesticides with seed in the furrow at the time of sowing.
Gall An abnormal growth of plant tissues, caused by the stimulus of an animal or another plant.
Generation The period from any given stage in the life cycle (usually adult) to the same stage in the offspring.
Granule Coarse particle of inert material (pumice, Fuller's earth, rice husks) impregnated or mixed with a pesticide. Used mainly for soil application, but sometimes for foliar application (pumice formulation).
Granule applicator Machine designed to apply measured quantities of granules.
Grease band Adhesive material (e.g. resin in castor oil, or 'Sticktite') applied as a band around a tree to trap or repel ascending wingless female moths, or ants.
Grub (White) A scarabaeiform larva; thick-bodied, with a well-developed head and thoracic legs, without abdominal prolegs, usually sluggish in behaviour; general term for larvae of Coleoptera.
Habitat The place where plants and animals live, usually with a distinctive boundary (e.g. field, pond, sand-dune, rocky crevice).
Hemelytron The partly thickened forewing of Heteroptera.
Hemimetabolous Insects having a simple metamorphosis, like that in the Orthoptera, Heteroptera, and Homoptera.
Herbivorous Feeding on plants (phytophagous).
Hibernation Dormancy during the winter, or cold season.
Hollow-cone Spray jet with a core of air breaking to give drops in an annular pattern.
Holometabolous Insects having a complete metamorphosis, as in the Diptera, Hymenoptera, Coleoptera, Lepidoptera.
Honey-dew Liquid with high sugar content discharged from the anus of some Homoptera.
Hornworm A caterpillar with a dorsal spine or horn on the last abdominal segment – larvae of Sphingidae.
Host The organism in or on which a parasite lives; and the plant on which an insect feeds.
Humectant Material added to a spray to delay evaporation of the water carrier.
Hyaline Transparent.
Hypermetamorphosis A type of complete metamorphosis in which the different larval instars represent two or more different types of larvae.
Hyperparasite A parasite whose host is another parasite.
Hythergraph A polygonal diagram resulting from plotting temperature means against rainfall.
Imago The adult, or reproductive stage of an insect.
Immigration The movement of individuals into a population.
Immune Exempt from infection.
Incompatible Not compatible; incapable of forming a stable mixture with another chemical.
Indicator Marker.
Inert A material having no biological action.
Infect To enter and establish a pathogenic relationship with a plant (host); to enter and persist in a carrier.
Infest To occupy and cause injury to either a plant, soil or stored products.
Injector A device for ejecting a pesticide below the soil surface, or into the transport system of a tree.
Insecticide A toxin effective against insects.
Instar The form of an insect between successive moults; the first instar being the stage between hatching and the first moult.
Intercropping The growing of two crops simultaneously in the same field.
Jet Liquid emitted from a nozzle orifice (in USA = nozzle).
Key pest An important major pest species in the complex of pests attacking a crop, with a dominating effect on control practices.
Lacquer Pesticide incorporated into a lacquer or varnish to achieve slow release over a lengthy period of time.
Larva The immature stages of an insect, between the egg and p having a complete metamorphosis; the six-legged first instap the Acarina.
Larvicide Toxicant (poison) effective against insect larvae.
LC_{50} Lethal concentration of toxicant required to kill 50% of large group of individuals of one species.
LD_{50} Lethal dose of toxicant required to kill 50% of a large group of individuals of one species.
Leaf area index (LAI) Ratio of leaf surface to soil surface area, relation to utilization of solar energy for photosynthesis.
Leaf miner An insect which lives in and feeds upon the cells between the upper and lower epidermis of a leaf; these being larvae of Agromyzidae (Diptera), Lyonetiidae and Gracillariidae (Lepidoptera), Hispidae (Coleoptera), etc.
Life table The separation of a pest population into its different age components (e.g. eggs, larvae, pupae, adults).
Looper A caterpillar of the family Geometridae, with only one pair of abdominal prolegs (in addition to the terminal claspers), and which moves by looping its body.
Macropterous Large, or long-winged.
Maggot A vermiform larva, legless, without a distinct head capsule (Diptera).
Miscible liquid (m.l.) A formulation in which the technical product is dissolved in an organic solvent which is then, on dilution, dissolved in the water carrier.
Mist blower Sprayer producing a fine air-carried spray.
Miticide Preferably called Acaricide.
Molluscicide Toxicant effective against slugs and snails.
Monoculture The extensive cultivation of a single species of plant.
Monophagous An insect restricted to a single host plant species.
Mortality Population decrease factor; death rate.
Mutualism The symbiotic relationship between two organisms in which both parties derive benefit.
Myamecodomatia
Natality Population 'increase' factor; birth rate.
Necrosis Death of part of a plant.
Nematicide Toxicant effective against nematodes (= eelworms).
Nocturnal Active at night.
Non-ionic surfactant A surfactant that does not ionize in solution and is therefore compatible with both anionic and cationic surfactants.
Nozzle 1. Air blast: nozzle using high velocity air to break up the spray liquid supplied at low pressure. 2. Anvil: nozzle in which the spray liquid jet strikes a smooth, solid surface at a high angle of incidence. 3. Cone (or swirl): nozzle in which the liquid emerges from the orifice with tangential velocity imparted by passage through one or more tangential or helical channels in the swirl chamber. 4. Hollow cone: nozzle in which spray jet has a core of air breaking to give drops in an annular pattern. 5. Fan nozzle: the aperture is an elongate horizontal slit, producing a fan-shaped spray pattern. 6. Deflector: nozzle in which a fan-shaped sheet of spray is formed by directing the liquid over a sharply inwardly curving surface.
Nymph The immature stage of an insect that does not have a distinct pupal stage; also the immature stages of Acarina that have eight legs.
Obtect pupa A pupa in which the appendages are more or less glued to the body surface (Lepidoptera).
Oligophagous (= Stenophagous) An animal feeding upon only a few, closely related, host plants; or it may be an animal parasite.

Onisciform larva A flattened platyform larvae, like a wood-louse in appearance.
Orifice (nozzle) velocity Velocity at which the spray leaves the nozzle orifice.
Ovicide Toxicant effective against insect or mite eggs.
Oviparous Reproduction by laying eggs.
Oviscapt Ovipositor formed from elongation of posterior abdominal segment.
Paint gun Type of small, hand-carried, air-blast machine.
Pantropical A species occurring widely throughout the tropical and subtropical parts of the world.
Parasite An organism living in intimate association with a living organism (plant or animal) from which it derives material essential for its existence while conferring no benefit in return.
Parasitoid An organism alternately parasitic and free-living; most parasitic Hymenoptera and Diptera fall into this category as usually only the larvae are parasitic.
Parthenogenesis Reproduction without fertilization; usually through eggs but sometimes through viviparity.
Parts per million (ppm) Proportion of toxicant present in relation to that of plant material on which it has been deposited. Usually applied in connection with the edible portion of a crop and its suitability for consumption.
Pellet Seed coated with inert material, often incorporating pesticides, to ensure uniform size and shape for precision drilling.
Penetrant Oil added to a spray to enable it to penetrate the waxy insect cuticle more effectively.
Persistence The term applied to chemicals that remain active for a long period of time after application.
Pest An animal or plant causing damage to man's crops, animals or possessions.
Pest density The population level at which a pest species causes economic damage.
Pest management The careful manipulation of a pest situation, after extensive consideration of all aspects of the life system as well as ecological and economic factors.
Pest spectrum The complete range of pests attacking a particular crop.
Pesticide A chemical which by virtue of its toxicity (poisonous properties) is used to kill pest organisms. A term of wide application which includes all the more specific applications – insecticide, acaricide, bactericide, fungicide, herbicide, molluscicide, nematicide, rodenticide, etc.
Pheromone (= Ectohormone). A substance secreted by an insect to the exterior causing a specific reaction in the receiving insects.
Phytophagous Herbivorous; plant eating.
Phytosanitation Measures requiring the removal or destruction of infected or infested plant material likely to form a source of reinfection or reinfestation. (See Crop Hygiene.) International phytosanitation refers to inspection of plants and seeds to prevent noxious pests and diseases from being brought into a country; often involves plant quarantine.
Phytotoxic A chemical liable to damage or kill plants (especially the higher plants), or plant parts.
Planidium larva A type of first instar larva in certain Diptera and Hymenoptera which undergoes hypermetamorphosis.
Poison bait An attractant foodstuff for insects, molluscs, or rodents, mixed with an appropriate toxicant.
Polyphagous An animal feeding upon a range of hosts.
Pre-access interval The interval of time between the last application of pesticide to an area and safe access to the area for domestic livestock, and man.
Predisposition Making a plant more susceptible to a pest or disease, usually as a result of genetic, cultural or environmental defects.
Preference The factor by which certain plants are more or less attractive to insects by virtue of their texture, colour, aroma or taste.
Pre-harvest interval The interval of time between the last application of pesticide and the safe harvesting of edible crops for immediate consumption.
Pre-oviposition period The period of time between the emergence of an adult female insect and the start of its egg laying.
Pre-pupa A quiescent stage between the larval period and the pupa; found in some Diptera and Thysanoptera.
Preventative A measure applied in anticipation of pest attack.
Proleg A fleshy abdominal leg found in caterpillars (Lepidoptera, sawflies), bearing a characteristic arrangement of crochets.
Proprietory name Distinguishing name given by the manufacturer to a particular formulated product.
Protective clothing Clothing to protect the spray operator from the toxic effects of crop protection chemicals. This may include rubber gloves, boots, apron, respirator, face mask, etc.
Protonymph The second instar of mites.
Pterostigma A thickened opaque or dark spot along the costal margin of the wing, near the tip (e.g. Odonata, Hymenoptera).
Pupa The stage between larva and adult in insects with complete metamorphosis; a non-feeding and usually inactive stage.
Puparium The case formed by the hardened last larval skin in which the pupa of Diptera is formed.
Quarantine All operations associated with the prevention of importation of unwanted organisms into a territory, or their exportation from it.
Recruitment The addition of new individuals to a population, usually by either birth or immigration.
Redistribution Movement of pesticide subsequent to the initial application to other parts of the plant, usually by rain.
Repellant A chemical which has the property of inducing avoidance by a particular pest.
Residue Amount of pesticide remaining in or on plant tissues (or in soil) after a given time, especially at harvest time.
Resistance The natural or induced capacity to avoid or repel attack by pests (or parasites). Also the ability to withstand the toxic effects of a pesticide or a group of pesticides, often by metabolic detoxification.
Rodenticide A toxicant effective against rodents.
Roguing The removal of unhealthy or unwanted plants from a crop.
Rostrum The beak or proboscis of Hemiptera.
Run-off The process of spray shedding from a plant surface during and immediately after application, when droplets coalesce to form a continuous film and surplus liquid drops from the surface.
Scarabaeiform larva A grub-like larva, with a thickened cylindrical body, well-developed head and thoracic legs, without abdominal prolegs, and sluggish in behaviour.
Scavenger An animal that feeds on dead plants and animals, on decaying matter, or on animal faeces.
Secondary pest Species whose numbers are usually controlled by biotic and abiotic factors which sometimes break down, allowing the pest to increase in numbers.
Seed dressing A coating (either dry or wet) of protectant pesticide applied to seeds before planting. Dry seed dressings are often physically stuck to the testa of the seed by a sticker such as methyl cellulose.
Semi-looper Caterpillar from the subfamily Plusiinae (Noctuidae) with two or three pairs of prolegs, which locomotes in a somewhat looping manner.

Semiochemicals Chemicals produced by one organism that incite a response in another organisin.
Siphunculi The paired protruding organs near the terminal end of the abdomen of Aphidoidea, also called cornicles, through which a waxy secretion is extruded.
Slurry Paste-like liquid used as a seed coating.
Smoke Aerial dispersal of minute solid particles of pesticides through the use of combustible mixtures.
Soil sterilant Toxicant added to, or injected into, soil for the purpose of killing pests and pathogens.
Solid cone Jet with air-core reduced to give a cone of spray droplets.
Solvent Carrier solution in which the pesticide (technical product) is dissolved to form the concentrate.
Spray 1. Air-carried: spray propelled to target in a stream of air. 2. Coarse: dispersion of droplets of mass median diameter over 200 μm. 3. Concentrate: undiluted commercial pesticide preparation. 4. Fine: dispersion of droplets of mass median diameter from 50–150 μm. 5. Floor: spray applied to the litter on the ground surface. 6. High-volume: over 1200 1/ha on bushes and trees; over 700 1/ha on ground crops (or over 400 1/ha according to definition). 7. Low-volume: spray of 250–600 1/ha on bushes and trees; 50–250 1/ha on ground crops (or 5–400 1/ha). 8. Median-volume: 600–1200 1/ha on bushes and trees; 250–700 1/ha on ground crops. 9. Mist: dispersion of droplets of 50–100 μm in diameter. 10. Ultra-low-volume: less than 50 1/ha on ground crops; less than 250 1/ha on trees and bushes (or less than 51 1/ha according to definition).
Spray angle Angle between the sides of a jet leaving the orifice.
Sprayer Apparatus for applying pesticide sprays; not to be confused with 'Spray operator'.
Spray operator Person operating a sprayer, and applying a spray.
Spread Uniformity and completeness with which a spray deposit covers a continuous surface, such as a leaf or a seed.
Spreader Material added to a spray to lower the surface tension and to improve spread over a given area (= wetter).
Spur An articulated spine, often on a leg segment, usually the tibia. A serrulate tibial spur is characteristic of the Delphacidae (Homoptera).
Stability The ability of a pesticide formulation to resist chemical degradation over a period of time.
Sticker A material of high viscosity used to stick powdered seed dressings on to seeds; two commonly used stickers are paraffin and methyl cellulose. A solution of methyl cellulose can be added to a spray to increase retention on plant foliage.
Stomach poison A toxicant (poison) which operates by absorption through the intestine after having been injested by the insect, usually on plant material.
Supplement (spray) (= Adjuvant).
Surfactant (= Spreader; wetter).
Susceptible Capable of being easily infested or infected; not resistant.
Swath Width of target area sprayed at one pass.
Symbiosis The general term for two organisms that live together in a partnership, sometimes beneficial; includes commensalism, inquilinism, mutualism, and parasitism.
Sympatric Having the same, or overlapping, areas of geographical distribution.
Synecology The study of a particular community.
Synergism Increased pesticidal activity of a mixture of pesticides above that of the sum of the values of the individual components.
Systematics The classification of animal and plant species into their higher taxa; sometimes regarded as synonymous with taxonomy.
Systemic A pesticide absorbed through the plant surfaces (usually roots) and translocated through the plant vascular system.
Sterilant A treatment or chemicals that induce sterility in an organism, i.e. prevent it from reproducing.
Taint Unwanted flavour in fresh or processed food from a pesticide used on the growing crop.
Target surface The surface intended to receive a spray or dust application.
Taxonomy The laws of classification as applied to natural history; identification of plant and animal species.
Technical product The usual form in which a pesticide is prepared and handled prior to formulation; usually at a high level of purity (95–98%) but not completely pure.
Tegmen The thickened and leathery forewing in the Orthoptera and Dictyoptera.
Tenacity The property of a pesticide deposit or residue to resist removal by weathering.
Tenacity index Ratio of the quantity of residue per unit area at the end of a given period of weathering to that present at the beginning.
Tolerance Ability to endure infestation (or infection) by a particular pest (or pathogen) without showing severe symptoms of distress.
Tolerance, permitted Maximum amount of toxicant allowed in foodstuffs for human consumption.
Toxicant Poison, or chemical exhibiting toxicity.
Toxicity Ability to poison, or to interfere adversely with vital processes of the organism by physico-chemical means.
Tracer Additive to facilitate location of a deposit, by radioactive or fluorescent means.
Translaminar A pesticide which passes through from one surface of a leaf to the other (from lamina to lamina) through the leaf tissue. (eg. Fenitrothion)
Translocation The uptake of a pesticide into part of a plant body and its subsequent dispersal to other parts of the plant body.
Trap crop Crop of plants (sometimes wild plants) grown especially to attract insect pests, and when infested either sprayed or collected and destroyed. Trap plants usually grown between the rows of the crop plants or else peripherally.
Trapping-out The removal of individuals from a pest population, in significantly large numbers, by means of trapping (often using u.v. light traps).
Triungulin larva The active first instar larva of Meloidae (Coleoptera), and Strepsiptera.
Vector Organisms able to transmit viruses or other pathogens either directly or indirectly. Direct virus vectors include insects, mites and nematodes.
Vermiform larva A legless (apodous), headless (acephalic), worm-like larva typical of some Diptera.
Vestigial Poorly developed; degenerate; non-functional.
Viviparous Giving birth to living young (Aphidoidea).
Volunteer Crop plant growing accidentally from shed seed; not deliberately cultivated.
Wireworm (Elateriform larva) The larva of Elateridae (Coleoptera); long; slender, well-sclerotized, thoracic legs but no prolegs, and few setae.

This glossary was originally based in part upon one produced for the Horticultural Education Association, UK, by Mr R. W. Marsh, OBE, late of Long Ashton Research Station, Bristol, whose assistance is gratefully acknowledged.

An excellent fairly recent published dictionary of relevance is by Lincoln, Boxshall & Clark (1982).

Appendix B Standard abbreviations

Units and general abbreviations

a.e.	acid equivalent
a.i.	active ingredient
°C	degrees Celsius
cm	centimetre
cv.	cultivar
e.c.	emulsifiable concentrate
g	gram
h	hour
ha	hectare
h.v.	high volume
i.r.	infra-red
kg	kilogram
km	kilometre
£	pound sterling
l	litre
LC_{50}	median lethal concentration
LD_{50}	median lethal dose
l.v.	low volume
m	metre
mg	milligram
min	minute
ml	millilitre
mm	millimetre
pH	hydrogen ion concentration
post-em	post-emergence
ppm	parts per million
pre-em	pre-emergence
RH	relative humidity
s	second
sp.	species
spp.	species (plural)
ssp.	subspecies
sspp.	subspecies (plural)
$	dollar
u.l.v.	ultra-low volume
u.v.	ultra-violet
var.	variety
vol.	volume
w.p.	wettable powder
w/w	weight for weight

Miscellaneous abbreviations

BPH	Brown Planthopper of rice
BC	Biological control
BSI	British Standards Institute
Cda	Controlled droplet application
GV	Granulosis virus
IPM	Integrated pest management/Insect Pest Management
EAG	Electroantennagram
HMSO	Her Majesty's Stationery Office, UK
OC	Organochlorine compounds
OP	Organophosphorous compounds
PHV	Polyhedrosis virus
PM	Pest management
SIRM	Sterile insect release method

Organizations

ADAS	Agricultural Development and Advisory Service (formerly NAAS), MAFF, UK
ARC	Agricultural Research Council, UK
AVRS	Asian Vegetable Research Station, Taiwan
BM(NH)	British Museum (Natural History), London, UK
CAB	Commonwealth Agricultural Bureaux, Slough, UK
CIAT	Centre for International Tropical Agriculture, Cali, Colombia
CIBC	Commonwealth Institute of Biological Control (headquarters), West Indies
CIE	Commonwealth Institute of Entomology, London, UK
CIP	International Potato Centre, Lima, Peru
CIH	Commonwealth Institute of Helminthology, St Albans, UK
CMI	Commonwealth Mycological Institute, Kew, UK
COPR	Centre for Overseas Pest Research, London, UK
CSIRO	Commonwealth Scientific and Industrial Research Organization, Canberra, Australia
EAAFRO	East African Agricultural and Forestry Research Organization, Nairobi, Kenya
EPA	Environmental Protection Agency, Washington, USA
EPPO	European Plant Protection Organization, Paris, France
FAO	Food and Agricultural Organization of the United Nations, Rome, Italy
GCRI	Glasshouse Crops Research Institute, UK
IAC	International Agricultural Centre, Wageningen, Netherlands
ICRISAT	International Crops Research Institute for the Semi-arid Tropics, Hyderabad, India
IITA	International Institute of Tropical Agriculture, Ibadan, Nigeria
IRRI	International Rice Research Institute, Manila, Philippines
ICIPE	International Centre for Insect Physiology and Ecology, Nairobi, Kenya
MAFF	Ministry of Agriculture, Fisheries and Food, UK (=DEFRA)
MARDI	Malaysian Agricultural Research and Development Institute, Selangor, Malaysia
NAAS	National Agricultural Advisory Service (now ADAS), UK
NAPPO	North American Plant Protection Organisation, USA
NVRS	National Vegetable Research Station, Wellesbourne, UK
ODM	Ministry of Overseas Development, UK
PBI	Plant Breeding Institute, Cambridge, UK

PESTDOC	Derwent Pooled Pesticidal Literature Documentation
TPRI	Tropical Products Research Institute, London, UK
US AID	United States Aid for International Development, USA
USDA	United States Department of Agriculture, USA
WHO	World Health Organization, Geneva, Switzerland
WICSCBS	West Indies Central Sugarcane Breeding Station, Barbados, West Indies
WRO	Weed Research Organization, Oxford, UK

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